DOCUMENT RESUME

ED 222 108 HE 015 451

AUTHOR Useem, Elizabeth
TITLE Education in a High Technology World: The Case of Route 128.
INSTITUTION Northeastern Univ., Boston, MA. Inst. for the Interdisciplinary Study of Education.
SPONS AGENCY National Inst. of Education (ED), Washington, D.C.
PUB DATE Jun 82
NOTE 83p.
AVAILABLE FROM 33 Mosman Street, Newton, MA 02165.

EDRS PRICE MF01/PC04 Plus Postage.
DESCRIPTORS College Role; Computer Science; *Education Work Relationship; *Employment Opportunities; Engineering; Financial Problems; Government Role; Higher Education; Industry; *Labor Force Development; Mathematics Instruction; Mathematics Teachers; Retrenchment; *School Business Relationship; *Science Careers; Science Instruction; Science Teachers; Secondary Education; Technical Education; *Technical Occupations; Technology
IDENTIFIERS Corporate Support; *Massachusetts (Boston)

ABSTRACT

The relationship between high technology firms and educational institutions in the Boston metropolitan area was studied. Attention was focused on the responsiveness of public schools, community colleges, and four-year colleges and universities to the demands of the industry for technically trained personnel. The influence of companies on educational policies and the development of links between the two institutions were also explored. Information was gathered from: personal interviews with 130 officials from education, industry, and government; a survey of 158 secondary mathematics and science teachers at high schools on Route 128; reanalysis of a national survey of American high school seniors in 1980 commissioned by the National Center for Education Statistics; and review of documents and reports. It was found that there is considerable interest on the part of students and school administrators at all levels of education in courses and programs of study that would lead to technical careers. However, the capacity of educational institutions to respond to student interest is limited by budgetary considerations. A shortage of staff and equipment exists in all programs. Industry support for the schools is concentrated mainly on baccalaureate and postgraduate degree programs. There are a few cases of mutually satisfying cooperation programs between the companies and other sectors of education; but, for the most part, school-industry ties are fragmentary, weak, and of short duration. It is concluded that despite new interest in industrial-education partnerships, it is highly unlikely that corporations will be able to provide schools with the resources traditionally supplied by government funds. A bibliography is appended. (Author/SW)

ED222108

EDUCATION IN A HIGH TECHNOLOGY WORLD:
THE CASE OF ROUTE 128

Dr. Elizabeth Useem

NORTHEASTERN UNIVERSITY

Institute for the Interdisciplinary
Study of Education

June, 1982

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY

Elizabeth Useem

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

This document has been reproduced as received from the person or organization originating it.

Minor changes have been made to improve reproduction quality.

• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

HE 015 451

Education in a High Technology World:
The Case of Route 128

Dr. Elizabeth Useem

Northeastern University

Institute for the Interdisciplinary
Study of Education

June, 1982

This study was made possible by a Faculty Fellowship funded by the National Institute of Education. Dr. Useem, a Northeastern University Faculty Associate during 1981-82, is an Associate Professor of Sociology at the University of Massachusetts, Harbor Campus, Boston. Additional copies of this report may be obtained by writing the author at 33 Mosman Street, Newton, Massachusetts 02165. (617-527-1247) Invaluable research assistance was provided by Tracey Boyce, Michael Bernard, Mary Greeley and Paula Amir.

SUMMARY

This study examined the relationship between high technology firms and educational institutions in the Boston metropolitan area. The research focused on the responsiveness of public schools, community colleges and four year colleges and universities to the demands of the industry for technically trained personnel. The influence of companies on educational policies and the development of links between the two institutions were explored as well. Information was gathered from several sources: personal interviews with 130 officials from education, industry and government; a survey of 158 secondary mathematics and science teachers at high schools on Route 128; reanalysis of a national survey of American high school seniors in 1980 commissioned by the National Center for Education Statistics; and numerous documents and reports.

There is considerable interest on the part of students and school administrators at all levels of education in courses and programs of study that would lead to technical careers. However, the capacity of educational institutions to respond to student interest is limited by budgetary considerations. A shortage of staff and equipment exists in all programs--high school mathematics and science, high technology vocational courses, two year post-secondary technical curricula, and engineering and computer science education. Industry support for the schools is concentrated mainly on baccalaureate and post-graduate degree programs. There are a few cases of mutually satisfying cooperative programs between the companies and other sectors of education but, for the most part, school-industry ties are fragmentary, weak, and of short duration. Despite new interest in industrial-education partnerships, it is highly unlikely that corporations will be able to provide schools with the resources traditionally supplied by government funds.

The Public Schools

Massachusetts public schools have been well-funded and have enjoyed a favorable academic reputation over the years. The percentages of students enrolled in mathematics and science courses are significantly higher than proportions enrolled in such classes in all other regions of the country. Massachusetts and New England students score slightly above the national average on a variety of achievement tests. However, declining enrollment and recent budget cuts are causing a deterioration in school programs, including those in mathematics and science. A generation of younger teachers has been laid off, class sizes are increasing in some schools, and needs for new equipment, supplies and textbooks are going unmet.

The most critical problem is the probable dissolution of a cadre of highly qualified, experienced mathematics and science teachers. Some schools are already losing these teachers to industry. And data from the teacher survey show that only two-fifths of these instructors plan to remain in public school teaching. The numbers currently being trained for these positions in colleges and universities are miniscule. Schools are having difficulty finding qualified

teachers, and as layoffs occur, collective bargaining contracts are allowing elementary teachers to displace less senior mathematics and science specialists in the junior high schools.

Vocational and industrial arts educators face similar problems in attracting qualified staff for electronics and computer courses and in obtaining adequate budgets for equipment. Their difficulties are compounded by recent federal cuts in occupational education funds.

While nearly all educators want to have productive collaborative ties with high technology industry, relations between schools and companies are strained, partly because of the support of the Massachusetts High Technology Council for Proposition 2½, a property tax reduction measure passed in 1980.

The Community Colleges and Other Two Year Schools

Public community colleges in Massachusetts are small and poorly funded. As a result, other training establishments, particularly proprietary schools, play a major role in providing electronics and other technicians to the labor force. Despite few resources, however, some community colleges have developed a range of technology-oriented offerings and student enrollments in them are growing. Enrollments at private and proprietary technical schools have risen as well. There are pockets of constructive training relationships between two year schools and high technology firms, and a few companies have made donations to the colleges. But as in the case of the public schools, relations with these schools are of marginal interest to most companies.

Uncertainties exist over workforce projections for technicians. Company officials in a few firms cautioned that technological changes are automating the work of some of their technicians, resulting in lower employment demand. Others, however, pointed to countervailing trends that will increase the need for technicians.

The Four Year Colleges and Universities

Massachusetts is a center for higher education. The state's schools train a disproportionate share of the nation's engineers. Like colleges and universities all over the country, enrollments in engineering and computer science have risen dramatically in response to the job opportunities in the high technology sector. The schools are not able to keep up with student demand, however, because of the lack of qualified faculty, an inadequate physical plant, and insufficient research and training facilities.

Some industrial leaders have helped to focus attention on the problematic conditions of engineering education, and have launched several initiatives to increase industry aid to these programs. The Massachusetts Institute of Technology continues to have close ties with companies and receives considerable financial support from them. Other colleges and universities have been less frequent beneficiaries of corporate largesse. A consensus has been reached among university administrators and industry leaders on the problems of engineering education and some of their solutions. But they disagree on the role that the federal government should play in alleviating the crisis that besets the schools,

with educators favoring greater involvement of the government and managers opposing it.

Student interest at all educational levels in Massachusetts is moving in a direction congruent with industry needs, but the capacity of educational institutions to respond to that demand remains in doubt.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
I. THE PUBLIC SCHOOLS	4
The Current Status of Massachusetts Public Education	4
The Status of Mathematics and Science Education in Seven Route 128 Communities	11
The Condition of Industrial Arts and Secondary Vocational Education	22
Industry-Education Relations	25
II. TWO YEAR POST-SECONDARY SCHOOLS	34
Enrollments in High Technology Programs	35
Relations with High Technology Industry	39
High Technology Influence on the Board of Regents of Higher Education	41
Barriers to Industry-Education Cooperation	43
A Note on Workforce Projections	45
III. FOUR YEAR COLLEGES AND UNIVERSITIES	48
Enrollment Trends	49
Obstacles to Expansion in Engineering and Computer Science Programs	53
The Industrial Response to the Engineering Education Crisis	55
Industry and Education: Views of One Another	60
The Question of the Engineering Shortage	65
IV. CONCLUSION	67
V. REFERENCES	69

INTRODUCTION

The Boston area is one of two major centers in the United States of technologically sophisticated industry. Its manufacturing economy, along with that of Santa Clara Valley in northern California, is both a microcosm and a harbinger of the new age of microelectronics that is emerging in industrialized nations. This study, which is similar in purpose and coverage to a study conducted in 1981 of California's Santa Clara Valley,[1] focuses on the relationship between high technology firms and educational institutions in the Boston metropolitan area.[2] The research examines the responsiveness of schools at all levels to a growing industry's demand for a better educated labor force, the influence of high technology firms on educational policies, and the development of ties between the two institutions.

A number of electronics and other science-based firms existed in the Boston area prior to 1940, but it was the massive federal support for war-related research during the early 1940s that provided the major impetus for the development of new technologies in the Boston region. A large number of new companies formed soon after the end of the Second World War, many of them spinoffs from research laboratories at the Massachusetts Institute of Technology, "the undisputed fountainhead of high technology firms in the area."[3] Route 128, the famed "Golden Horseshoe" built in the late 1940s and early 1950s, eventually became the home for over a thousand high technology companies. Today, approximately 33 percent of the state's manufacturing workforce is employed in high technology firms, the bulk of them in the Route 128 area or on Route 495, the circumferential highway lying outside of Route 128. Employment growth in the industry has been particularly dramatic since 1975, increasing by a third (32 percent) between 1975 and 1979.[4] Although two-thirds of Massachusetts workers are employed in the service sector, the fastest growing part of the regional economy since the 1950s, and while the number of workers in New England employed in high technology companies still does not exceed the number employed in the textile mills in previous years,[5] the importance of the presence of the high technology companies cannot be overestimated. For example, high technology firms have higher growth rates and invest more heavily in plant and equipment than other manufacturing firms. In 1981, $0.41 out of every dollar of capital spending by all manufacturing companies in New England was accounted for by high

technology companies.[6] As labor economists have often pointed out, the periodic revitalizations of the regional economy have historically depended on the growth of new, technologically innovative firms.[7]

While the high technology sector in the postwar period was expanding, older industries in the state such as textiles and leather goods were in a period of significant decline.[8] The recent spurt of growth of science-based industry since 1975, particularly coming as it did on the heels of a recessionary period from 1970-75 in the state, has led many business and political leaders to view high technology firms as a kind of savior of the Massachusetts economy. The fact that the development of the industry rescued Massachusetts from the economic doldrums is one reason why high technology executives have significant political clout when they choose to act collectively. Their main trade association, the Massachusetts High Technology Council, is a highly visible corporate interest group. Founded in 1977, its membership includes 124 companies which together employ 115,000 Massachusetts workers. Although many high technology companies are not members (e.g., Raytheon, Polaroid, and General Electric), the Council is widely regarded as the voice of that industrial sector.

The Council has been particularly effective in publicizing labor shortages of technically trained personnel. Industry leaders in Massachusetts, along with the American Electronics Association, stress that despite the current business slowdown, there is an increased long term demand for engineers, computer scientists and programmers, electronics and computer technicians, computer operators, and other tradespeople such as drafters.[9] Government agencies and other economists have made similar forecasts. The Council has made a concerted effort since its founding to encourage post-secondary institutions in Massachusetts to produce such skilled professional and technical workers. Its members argue that their companies' explosive growth has led to personnel shortages and these are now a constraint on continued expansion. Recently, its leaders have also expressed a need to upgrade high school mathematics and science programs, to develop better career awareness among secondary students, and to introduce computer literacy in the school curriculum. This study examines the inclination and capacity of educational institutions in the Greater Boston area to respond to this

projected demand for skilled technical workers by high technology firms. The research also focuses on the ties which exist between industry and education and the factors which promote or hinder collaborative efforts between the two.

This study draws on several types of information. One hundred and thirty interviews with officials from education, industry and government were conducted between September, 1981, and April, 1982.[10] A broad range of documents, studies, and reports on high technology and education in Massachusetts was assembled. A survey was conducted of mathematics and science teachers in eight secondary schools in the Route 128 area. And data on New England high school seniors, drawn from a national sample of 28,000 students were obtained and analyzed from the High School and Beyond study of the National Center for Education Statistics.[11] Where relevant, comparative data on California is included.

I. THE PUBLIC SCHOOLS

The Current Status of Massachusetts Public Education

Massachusetts has traditionally given high priority to its public schools. In 1980 it ranked fourth among the states in the absolute amount of money it spent per pupil,[12] and sixth in expenditures for public schools as a percent of personal income.[13] California, by contrast, places 48th among the states on the latter measure.[14] Teachers salaries are somewhat above the national average, $18,288 compared to $17,400 nationally in 1980,[15] and the pupil teacher ratio has been lower than the national average.[16] The state, however, has proportionately fewer children than the national average in gifted and talented programs.[17] According to the 1980 census, approximately three fourths (76 percent) of Massachusetts residents 25 years of age and over have graduated from high school compared to 66 percent nationally, and almost one quarter have four years of college compared to 16 percent in the nation.[18] Levels of educational attainment in New England, however, are lower than Pacific and Mountain States.[19]

Students in high schools in New England and the rest of the Northeast are much more likely than students from other parts of the country to be enrolled in an academic curriculum and to take mathematics and science courses (Table 1.1). Data from Massachusetts students taking the 1981 Scholastic Aptitude Tests show the same pattern (Table 1.2). Regional differences in the percentages of students taking mathematics and science courses are quite striking (Tables 1.3 and 1.4). According to the High School and Beyond survey, 54 percent of New England secondary students take three years or more of mathematics compared to 26 percent of California students. And 36 percent of those from New England have three or more years of science education compared with only 13 percent in California. While 19 percent of the nation's 1980 high school seniors had taken physics, 30 percent had done so in New England. Almost half (49 percent) of New England seniors have had chemistry, a percentage considerably higher than the national average (37 percent) or that of California (32 percent). In fact, in all academic subjects except social studies, New England students

Table 1.1

Percentage of 1980 High School Seniors in General, Academic, and Vocational Curriculum by Geographic Region

	New England	North-East*	South	North Central	West **	Pacific
Academic	47%	51%	33%	35%	34%	33%
General	25	24	39	40	45	47
Vocational	28	25	28	24	20	21

*Includes New England
**Includes Pacific

Source: High School and Beyond, National Center for Education Statistics, 1980.

Table 1.2

Selected Data on 1981 Students Taking Scholastic Aptitude Tests (SATs)

	National	Massachusetts	California
Percentage of Eligible Seniors Taking SATs	33%	63%	36%
Verbal Score	424	422	426
Math Score	466	462	475
Parents' Median Income	$24,100	$21,700	$26,300
Estimated High School Grade Point Average	3.06	2.90	3.13
Number of Years of Study of Mathematics	3.52	3.72	3.29
Number of Years of Study of Biological Science	1.40	1.45	1.32
Number of Years of Study of Physical Science	1.79	1.87	1.33

Source: The College Board, "College Bound Seniors, 1981" - National, Massachusetts, California.

Table 1.3

Cumulative Percentage of 1980 High School Seniors Taking Varying Amounts of Mathematics and Science Coursework, by Geographic Region

	Amount of Coursework	New England	North-East*	South	North Central	West**	California
Mathematics	1 year or more	98%	96%	96%	89%	91%	90%
	2 years or more	84	79	73	60	58	58
	3 years or more	54	48	36	29	24	26
Science	1 year or more	92	93	92	86	90	88
	2 years or more	65	66	56	48	44	41
	3 years or more	36	35	20	21	15	15

*Includes New England
**Includes California

Source: High School and Beyond, National Center for Education Statistics, 1980.

Table 1.4

Percentage of 1980 High School Seniors Taking Mathematics, Science, and Selected Courses

Course	National	California	New England
Algebra I	79%	79%	83%
Algebra II	49	49	62
Geometry	56	57	68
Trigonometry	26	24	32
Calculus	8	8	10
Physics	19	17	30
Chemistry	37	32	49
Family Life or Sex Education	48	60	33
Alcohol or Drug Abuse Education	39	51	31

Source: High School and Beyond, National Center for Education Statistics, 1980

have had greater amounts of coursework than their West Coast counterparts. The latter, however, were much more likely to have carried a family life or sex education course (60 versus 33 percent), and a class in alcohol and drug abuse education (51 versus 31 percent).

New England students do a little more homework than the national average (Table 1.4), although the percentages are not impressive in absolute terms. Thirty-one percent of the 1980 seniors in the High School and Beyond study had five or more hours of homework a week compared to 25 percent nationally. The students are equal to the national average in the percentage who miss five or more days of school a year for reasons other than illness (21 percent), while California reports a high proportion (29 percent) doing so. New England seniors are a little more likely to be tardy to school compared to national norms but are significantly more punctual as a group than California seniors (Table 1.6).

Variations by state in levels of academic achievement are difficult to assess since most national studies group students by region. Thus, for purposes of this analysis, data on the Northeast or New England will be used in addition to the few state reports which are available. Comparisons of Scholastic Aptitude Tests (SAT) scores between states are available, but they are not particularly useful since the proportion of seniors taking the test varies from state to state. Nationwide, approximately one third of all eligible seniors take the test but a much larger percentage, 63 percent, do so in Massachusetts. As a result of a larger pool of students taking the test, the SAT scores of Massachusetts students are slightly lower than the national average. The state's pupils scored 422 in the verbal portion of the test compared to 424 nationwide, and 462 the mathematics test compared to 466 among their counterparts in the rest of the nation (Table 1.2).[20] Declines in students' scores nationwide have been paralleled by a decline of similar magnitude among New England students since comparative data became available in 1972.[21]

There is evidence that Massachusetts and New England students achieve above students in other regions. Massachusetts has the seventh highest cutoff score required for students to qualify as semi-finalists for a National Merit Scholarship compared to other states.[22] A 1980 study of

Table 1.5

Percentage of 1980 High School Seniors Reporting
Amount of Time Spent on Homework Per Week

Average Hours Per Week	National	New England	California
Less than 5	68%	62%	69%
Between 5 and 10	18	21	17
More than 10	7	10	7
No homework is ever assigned	4	3	4
I have homework, but I don't do it	4	5	3

Source: High School and Beyond, National Center for Education Statistics, 1980.

Table 1.6

Percentage of 1980 High School Seniors Reporting
Absenteeism and Tardiness

	National	New England	California
5 days or more absent this year for reasons other than illness	21%	21%	29%
5 days or more late to school this year	19	23	31

Source: High School and Beyond, National Center for Education Statistics, 1980.

achievement was conducted for the Department of Defense of a national representative sample of 12,000 men and women ages 18 to 23. The results showed that those from New England scored highest on the Armed Forces Qualifying Test compared to young adults in eight other regions of the country (Table 1.7). Achievement scores from the 1980 High School and Beyond survey show New England students scoring several points above the national average in reading and mathematics (Table 1.8). The most comprehensive evaluations of achievement are those of the National Assessment of Educational Progress (NAEP). Those studies have consistently shown students from the Northeast (which includes some Middle Atlantic states) to have the highest scores in mathematics and science followed by the Central, West and Southeastern states in that order. Nine-year-olds in the Northeast also lead other regions in reading scores although thirteen and seventeen-year-olds generally rank second behind those in the Central states. Black students from the Northeast outscore black students from other regions at all ages in the reading assessment.[23]

The Massachusetts State Department of Education has conducted several statewide tests with some of the NAEP items so that regional and national comparisons could be made. The results of those surveys conducted between 1974 and 1978 show a mixed pattern. The state's students score above the national average in reading, mathematics, and some portions of the writing examination. In science, nine-year-olds also scored above the national average, but the rankings of the 17-year-olds placed them at the overall U.S. average. On some of the writing subtests, Massachusetts scored below regional and national averages.[24] Analyses of test results from the state's first mandatory testing of basic skills in 1981 show that Massachusetts pupils are significantly weaker in writing than they are in reading and math.[25] Thus, while some comparative weaknesses are present, students from Massachusetts and the surrounding region appear to have somewhat higher achievement levels than their counterparts elsewhere in the country.

However, the current demographic, economic and political environments within the state are having a destabilizing effect on public education.

Table 1.7

Mean Percentile Score on 1980 Armed Forces Qualifying Test, Ages 18-23, By Region

	New England	West North Central	Middle Atlantic	East North Central	Mountain	Pacific	West South Central	South Atlantic	East South Central
Mean Percentile Score	60	58	53	52	52	50	48	44	42

Source: Profile of American Youth: 1980 Nationwide Administration of the Armed Forces Vocational Aptitude Battery, U. S. Department of Defense, 1982.

Table 1.8

Reading and Mathematics Test Scores of 1980 Seniors

Test Score	National	New England	California
Reading (Mean)	49.64	51.19	49.85
(Median	49.95	52.41	49.98
Math-Part I (Mean)	49.60	52.10	50.48
(Median)	49.39	52.62	50.66
Math-Part II (Mean)	49.67	51.15	50.14
(Median)	48.06	51.95	51.31

Source: Student Achievement in California Schools, 1980-81 Annual Report, California State Department of Education, 1981; High School and Beyond, National Center for Education Statistics, 1980.

Student enrollment, which peaked in 1973-74, has declined approximately 22 percent since then, causing widespread layoffs of teachers and alterations in the curriculum and organization of schools. The problem is particularly acute in New England which has historically been characterized by low fertility rates.[26] The only area of the country with a lower fertility figure than that of Massachusetts currently is Washington, D.C.[27] One demographer estimates that only half of the females in the New England cohorts born during the mid-to-late 1950s will have more than one child.[28]

A second dramatic influence on schools in recent years is decreased financial support for public education. For the last several years, municipal budgets were held to a four percent increase at a time of double digit inflation. And in November, 1980, Massachusetts voters overwhelmingly approved Proposition 2½, a local tax reduction scheme similar to California's Proposition 13.[29] As a result, during the 1981-82 school year, the systems' budgets were cut an average of seven percent which, if inflation were taken into account, amounts to a 14 percent budget reduction. There was a 16 percent reduction in school staff in local school districts statewide including a 12 percent cut in the professional staff (approximately 7,000 teachers, counsellors and specialists). Another 2,000 to 4,000 will most likely be terminated by fall, 1982. Some of the reductions were due to declining enrollment, which averaged 4.2 percent across the cities and towns in 1981-82. One hundred and sixty three school buildings were closed as a direct result of 2½ alone, and half the local school districts established user fees for such services as athletics and instrumental music lessons.[30] At least 60 of the state's school superintendents announced their retirements or resignations during this school year, a dramatic increase from the average of 15 in previous years.[31] Thus, the twin effects of declining enrollment and budget reductions are creating a profoundly transformed environment within which public schools must operate.

The Status of Mathematics and Science Education in Seven Route 128 Communities

Six communities with the highest concentrations of high technology firms in the Route 128 area were selected for study along with one other Route 128

municipality where many technical professionals reside. Eight high schools are included in the research. Two of the communities are upper middle class, another two are middle class, while the other three are largely blue collar in their socioeconomic makeup. Interviews with at least one high ranking administrator in each of the seven systems and with the sixteen chairs of the secondary mathematics and science departments were conducted. A survey was conducted of 241 mathematics and science teachers in the eight schools. Sixty-six percent (158 people) of the teachers responded to the survey questionnaire. Of special interest were student enrollment trends, the impact of budget restrictions, and teacher staffing patterns.

Enrollments in mathematics and science courses, usually prerequisites to professional technical careers, are relatively high in these eight high schools (Table 1.9). Sixty to 95 percent of the students in each school are enrolled in science courses at any one time. The figures for mathematics enrollments range from 80 to 99.8 percent; five schools have more than 90 percent of their students enrolled in mathematics courses. The popularity of mathematics and science is little related to the social and economic status of the community. In one of the blue-collar high schools, 90 percent of the students are enrolled in mathematics, 14 percent are carrying computer programming courses, and 95 percent are taking science subjects. Several schools had made a concerted effort to enroll non-college bound students and females into science and mathematics courses. Five of the eight schools report an increasing student enrollment in science courses during the past several years, and six schools report similar growth in mathematics enrollments. Most of these increases are in the third and fourth year courses. No school is experiencing a drop in the percentage of its students in math and science enrollments. These upward trends contrast with those in California schools; four of eight school-system officials in Silicon Valley reported that mathematics and science enrollments were decreasing.

These results also show that Route 128 students go well beyond school district science and mathematics minimum requirements for graduation. Most of the systems require one or two years of high school mathematics and one

Table 1.9

Percentage of Secondary Students Enrolled in Mathematics and Science Courses* in Eight Route 128 High Schools, 1981

	School							
	A	B	C	D**	E**	F	G**	H**
Math Courses	92%	88%	94%	90%	85%	99.8%	90%	80%
Science Courses	87	64	70	88	60	75	95	65

*The few students who take more than one science or math course at a time are double-counted here.

**School has grades 10-12 only — other schools are grades 9-12.

Table 1.10

Percentage Reductions in School Professional Staff, School Budget and Student Enrollment in Seven Route 128 School Systems and the State of Massachusetts, 1981-82

	School System							
	A	B	C	D	E	F	G	*Massachusetts
Percentage Change in School Budget from 1980-81.	+6.3%	-1.1%	-13.0%	-1.3%	-0.0%	-2.3%	-11.2%	-7%
Percentage Reduction in Professional Staff from 1980-81	-9.9%	-10.5%	-15.4%	-8.1%	-10.5%	-19.3%	NA 25 Tenured Teachers "riffed"	-12%
Percentage Decline in Student Enrollment from 1980-81	-7.8%	-3.1%	-7.9%	-6.5%	-6.4%	-6.5%	-8.5%	-4.2%

*Source of Massachusetts Data: Massachusetts Association of School Committees, "The Impact of Proposition 2½ on Public Schools," April, 1982.

year of high school science (two years for college preparatory students in several schools), but students take significantly more courses. Three or more years of mathematics courses and two to three courses in science are typical for the majority of students at these schools. One school which has no mathematics requirement for graduation has almost 100 percent of its students taking this subject.

California and other states are trying to boost enrollments in science and mathematics by changing state graduation requirements and entrance requirements to the state's public colleges and universities. For example, the University of California will begin requiring three years of high school mathematics for entering freshmen in 1986, and the California State University system will require two years. Governor Jerry Brown recently exhorted Silicon Valley students to take more courses in math and science. A magnet school stressing science, math and technology courses is being planned by the Los Gatos Joint Union High School District and the Fremont Union High School District in the Valley.

While the Boston area schools are experiencing modest percentage increases in math and science enrollments, they are witnessing an enormous upsurge of student interest in computers. One secondary school system which had 23[illegible] students enrolled in computer electives in 1973 now has 680 students taking such courses. Yet many fear that since students are now often exposed to computers in elementary and junior high school, they will be frustrated by the lack of access to advanced course offerings at the senior high level. Every school administrator complained about the lack of computer hardware in the face of accelerating student demand. However, teachers at most schools, usually in the mathematics department, have been quite willing, even eager, to retrain in order to teach these courses. Several districts have used creative methods to stimulate teacher retraining. For example, one school system had trained 375 school staff out of 700 (including some custodians and secretaries) in a 30 hour course in BASIC through an Occupational Education grant from the state. Another system trained most of its mathematics faculty to teach computer courses through a "buddy system" where one teacher proficient in computers co-taught a course with a novice. While interest in computers

is "phenomenal," in the words of several administrators, there is little in the way of state or federal guidance or support for curriculum development or equipment acquisition. Unlike California, where at least county education officials provide leadership in establishing computer curricula, Massachusetts school districts have to go it alone in this area of instruction. There is no centralized teacher consortium or computer education in the Boston area either, unlike Silicon Valley where the Computer Using Educators group provides programs and services to further this pedagogical effort. There is a proliferation of smaller groups, newsletters and conferences in the Bay State but no one organization or government agency plays a coordinating role.

As student interest in science, mathematics and computers grows, school budgets are being reduced. All but one of the seven cities and towns studied experienced an absolute cut in their school budget in 1981-82. Professional staff reductions ranged from 8 percent to 19 percent, with an average of 12 percent for all towns, the same as the statewide percentage. Declines in enrollment averaged 6.7 percent in 1981-82, slightly above the average for the state (Table 1.10).

While cuts in high school programs have been most pronounced in athletics, industrial arts, music and assorted activities and clubs, there have also been financial reductions affecting the teaching of science and mathematics. Six of the eight science departments and half of the mathematics departments studied lost staff positions during 1981-82. Math teachers are less likely than science teachers to be laid off because of increased student demand for computer electives and small remedial courses. Eleven of sixteen departments have had their budgets for equipment, supplies and texts cut or level-funded in the last year. The chairs, particularly in the science departments, felt that these financial reductions were especially harmful because there has been such dramatic inflation in the costs of chemicals, glassware and textbooks. Six of the eight high schools are now using mathematics and science textbooks seven or eight years rather than the previous standard of five years. Two of the schools had lost funding for a faculty person to serve as coordinator of the school's mathematics team. All of the schools believed

that financial constraints had prevented them from acquiring the computer hardware necessary to accommodate student demand.

In addition to these reductions, one school lost a remedial mathematics laboratory and another lost the double laboratory period used in some science courses in the 1981-82 school year. Three schools had teacher sabbaticals abolished or in-service training programs eliminated. Four science departments and one mathematics department experienced an increase in class size or required teachers to take on an additional class. One school had to eliminate some of its ability groupings. Another cut eight courses from its science curriculum. Statewide, a number of towns eliminated the position of science coordinator, particularly at the elementary school level. Field trips to Boston's Museum of Science dropped by 25 percent during this first year of implementation of Proposition 2½. Overall, two thirds of the teachers surveyed in the eight high schools claimed that cuts or constraints in the school budget had hurt courses in their discipline. They singled out lack of money for equipment, supplies, texts and computers as their major concern followed by the growth in class size. It should be noted, however, that class sizes are still quite reasonable, around 25 students per class, and are significantly smaller than those in California.

The most serious problem, however, lies with the teaching staff itself. Recent national and state studies have documented the attrition of experienced mathematics and science teachers, a dramatic drop in newly certified graduates in those fields (a 65 percent decline in science education graduates and a 77 percent decline in mathematics education graduates between 1971 and 1980), and the misassignment of unqualified teachers to cover courses in mathematics and science.[32] These studies show that the problems in the Northeast are less severe than in the rest of the country. The pool of newly certified candidates is larger (Table 1.11), and the percentage of newly-employed but unqualified science and mathematics teachers is sharply lower--nine percent--than the national average of 50 percent. The percentage in Pacific Coast states is an astounding 84 percent (Table 1.12).

Nevertheless, it was apparent from the interviews and questionnaire data that the supply of qualified mathematics and science teachers is also becoming

Table 1.11

Number of People Granted Certification to Teach Secondary Mathematics and Science in Massachusetts, 1972-1981

	Mathematics	Chemistry	Physics	Biology	General Science	Earth Science
1972	891	246	154	417	950	64
1981	(157)*	(49)*	(38)*	(98)*	(226)*	(30)*
	315	119	62	268	457	49
Percentage Decline	-65%	-52%	-60%	-36%	-52%	-23%

*Veteran teachers, included in the total in each cell, who are adding on an extra certification.

Source: Massachusetts State Department of Education.

Table 1.12

Percentage of Newly-Employed, But Unqualified Science and Math Teachers

Census Region	1980-1981	1981-1982
Pacific States	75%	84%
Mountain States	44	43
West North Central States	26	43
West South Central States	63	63
East North Central States	23	32
East South Central States	43	40
Northeastern States	11	9
Middle Atlantic States	40	46
South Atlantic States	48	50
NATIONWIDE	45	50

Source: James Shymansky, National Science Teachers Association, Washington, D.C., 1982.

a serious problem in the Boston area. All of the department chairs interviewed stated that the pool of candidates was very small and five of the eight schools reported difficulty in finding qualified teachers in those subjects, especially physics. "Five years ago we had over two feet of job applicants' folders and now we have one inch," reported on mathematics department chair. One school system had experienced an 88 percent drop in applicants in all teaching fields in the last few years. "We are going to have a terrible shortage of teachers" warned the Assistant Superintendent. Many administrators expressed concern about the quality of new recruits. "We're getting the crumbs," commented one science chair. Another administrator admitted that "today we'll take any warm body" to teach mathematics and science. Indeed, the average SAT scores of 1981 Massachusetts college-bound seniors who chose education as their intended major were abysmal: a verbal score of 383 and a mathematics score of 409.

Few students in Massachusetts colleges and universities are interested in becoming teachers. Only 76 seniors who took the SATs in 1981 (0.2 percent of the test-takers) expressed an interest in becoming secondary education teachers. Most of the Route 128 schools studied do not have student teachers in science or mathematics, or other subjects for that matter, and many schools no longer have a Future Teachers Club. Able students are no longer encouraged by their teachers, parents or friends to choose education as a career. The numbers of students graduating in science and mathematics education is miniscule. For example, Boston State College (recently absorbed into the University of Massachusetts at Boston) is graduating no students in physics and chemistry education and only one or two in mathematics education; Northeastern University is turning out no one in secondary physics, one in chemistry and one in mathematics; Boston University has a total of two students graduating in science education and 11 in mathematics education. (In Massachusetts, a trainee in secondary education must major in a substantive discipline and can only minor in education.) Lowell University has abolished its undergraduate secondary education department and other local schools are considering the same option. Half of the new certifications in mathematics in 1981 in Massachusetts were veteran teachers "adding on" an

additional certification, by taking six additional courses, in order to save their jobs. These "add-ons" are not truly qualified to teach more than introductory courses.

While officials at the schools studied are having an increasingly difficult time finding qualified applicants in mathematics and science, both the questionnaire and interview data reveal that they have not yet resorted to misassigning unqualified teachers already on the staff to teach these courses. These findings confirm the Northeast pattern documented in national studies. However, misassignment does appear to be a growing problem in junior high schools were senior elementary teachers with a K-8 certification are "bumping" less experienced junior high math and science specialists. This was the case in four of the seven school systems. Several administrators believed that these senior elementary teachers were clearly less qualified than the specialists they had replaced. Many expressed the fear that misassignment would become a problem at the secondary level in the future.

Staff attrition is a serious problem in two schools. One of the two had lost five math teachers in the last three years to jobs in the better paying high technology sector. Another three high schools were losing approximately one a year to such jobs. Three schools, those in the most affluent communities least affected by budget cuts, claimed that such losses were not a problem, but the chairs expressed concern that it would become so in the near future. Their fears are borne out in the questionnaire survey of teachers which revealed widespread demoralization among the mathematics and science staff. The teachers, over two-thirds of whom are male, average 16 years of experience, the same as the national average for secondary mathematics and science teachers. By national standards, they are an extremely highly educated group: 81 percent, compared to approximately 50 percent of the secondary mathematics and science teachers nationally,[33] have an advanced post-graduate degree, and many have further course work beyond that. All of the science chairs and two-thirds of the mathematics chairs had participated in National Science Foundation programs of study available in the 1960s and early 1970s.

One of the sources of teacher malaise is apparent from the fact that only seven of 158 teachers are under the age of 30 (Table 1.13). Only two of the respondents have four or fewer years of teaching experience. One science department did not have a single teacher under the age of 40. This age distribution is the source of much concern among those surveyed. According to the survey, only 41 percent of the mathematics and science teachers in the Route 128 high schools are planning a permanent career in teaching or school administration (Table 1.14). The rest are either expecting to be laid off (12 percent) or are seriously considering leaving teaching (47 percent). The proportion expressing such feelings varied by school: in the system with the largest budget cut, every math teacher who responded to the survey wanted to leave teaching; in another system, two-thirds of the science teachers wanted to remain in the profession. Of course, teachers have always had high rates of attrition, but much of that was traditionally due to females in their twenties leaving teaching when they had children and males moving up to administrative positions. But these Route 128 schools have senior staffs who would normally not be expected to have such a high projected turnover. Thus, the fact that almost three-fifths of them are seriously considering a career change is cause for some alarm.

The percentage of mathematics teachers wanting to leave is the same as that of science teachers. However, only 6 out of 19 physics teachers in the sample said they want to continue their teaching careers, a lower fraction than that of teachers in other mathematics and science fields. Ironically, at a time when there is such a shortage of physics teachers, four of these teachers believe they are going to be laid off. Several chairs commented that when mathematics and science teachers are "riffed," few try to get another teaching job. ("It's the elementary teachers who hang on," said one school administrator.) Teachers who are younger and less experienced are more likely than others to be thinking about a career change. Of the seven teachers under 30, only two believed they would stay in teaching. Of those who are considering a career change, 60 percent said they would seek a job with a high technology company or

Table 1.13

Sex, Age, Years of Experience and Education of Secondary Science and Mathematics Teachers in Seven Route 128 (Boston Area) Communities, 1982

	Route 128 Teachers	
Sex:	Male	69%
	Female	31%
Age:	Under 30	5%
	30-40	43%
	40-50	33%
	Over 50	20%
Years of Teaching Experience:		16
Highest Educational Degree:	B.A. or B.S.	19%
	M.A. or M.S.	76%
	Ph.D. or Ed.D.	5%

Table 1.14

Future Career Plans of Secondary Science and Mathematics Teachers in Seven Route 128 School Systems

	Percentage Response
Planning a Permanent Career in Teaching and/or Educational Administration	41%
Very seriously considering leaving teaching for another field	22
Planning to leave teaching	25
May be laid off	12

a job that in some way utilized their mathematical or scientific expertise (often in computers). Their reasons for wanting to leave are twofold: declining job satisfaction and inadequate salary compensation. Typical comments the questionnaire included:

> "I'm tired of the long hours and low pay. Nobody except teachers care about the education of children."
>
> "Teaching is now a dead-end occupation."
>
> "I'm tired of teaching and the future looks bleak."
>
> "The teaching environment becomes less pleasant each year."
>
> "I love teaching but it's wearing me out. There are too many alienated kids to face everyday."
>
> "Working conditions are deteriorating. I want to leave Massachusetts and its anti-education attitude."
>
> "Teaching is a luxury I can no longer afford."
>
> "There is no room for growth, no reward to excellence in teaching. Salaries do not keep pace with inflation."

The most serious problem, then, in high school mathematics and science instruction in these Route 128 high schools is the possible dissolution of a highly qualified cadre of teachers with no new cohort of trained people to take its place. With teaching salaries beginning around $11,000-$13,000, students with skills in these fields can often find alternative employment at almost double that figure. Job security, once a strong point of teaching, no longer exists. Moreover, the veteran teachers surveyed felt that the quality of students' work is not improving--indeed, two-fifths felt that student academic performance had slipped in the last five years. With equipment cuts, larger classes, reductions in professional development opportunities, it is not surprising that teachers are demoralized. The shortage of qualified teachers in all fields will become particularly apparent in the mid-to-late 1980s when enrollments begin to rise at the elementary level, as a large number of teachers hired during the boom years of the 1950s retire, and as the full impact of the decline of newly trained teachers is felt.

The Condition of Industrial Arts and Secondary Vocational Education

Industrial arts courses and high school vocational training programs have problems similar to those of mathematics and science departments: a st

shortage of qualified teachers in certain fields, a loss of teachers to industrial jobs in several schools, and inadequate funding for modern equipment. Interviews were conducted with occupational-education directors in the seven Route 128 school systems and directors of two regional vocational high schools on Route 128. All of the school systems were having difficulty hiring instructors for electronics and computer courses. In one high school, all three electronics instructors had left in the last three years for jobs in private industry where they made substantially higher salaries. Vocational educators are paid $13,000 to $25,000, a scale that cannot compete with industrial compensation. Several schools had to lay off teachers in the last few years. One system had riffed three vocational teachers in 1981-82, one of whom had 25 years of experience. As a result of the staff cutbacks, the machine shop program was scaled down and merged with the program in metal shop.

Industrial arts and vocational education have been especially hard hit by budget cuts. Much of their budget is tied up in equipment and supplies which are inflating rapidly in cost. Three school systems had relatively good equipment and there were funds to maintain it. But five of the nine schools now have no money to replace equipment. "The budget cutting process has been devastating," claimed one occupational education coordinator who had seen his annual capital outlay budget slashed from $10,000 to zero. Local tax cuts are compounded in occupational programs by the substantial reductions in federal vocational funds under President Reagan. One of the comprehensive high schools has recently started a word processing course and an electronics curriculum with federal occupational education funds, but the coordinator feared the loss of even that support in the future.

The highly regarded 27 regional vocational-technical high schools in Massachusetts are experiencing a real crisis in funding. They derive their support from assessments of their member school districts which, during the current funding reductions, are more reluctant to give money to a school which may take only a few of the district's students. There was no special provision made for the funding of regional schools in the Proposition 2½ legislation, and these schools got less state aid proportionally in 1981-82

than local school districts. The first programs to be cut were courses that served post-secondary students. But next year, according to a state vocational education administrator, the budget reductions will be "getting at the heart of program offerings." One superintendent said that in two years, his schools would have to abolish some programs because the current capital outlay budget is $50,000 less than what it should be to keep the programs from becoming obsolete. He now spends most of his time on budgetary matters rather than on curriculum and administration, going from town meeting to town meeting pleading for adequate funding. Among other cuts, the school has eliminated seven staff positions, halved the teacher substitutes and reduced late bus service. Another superintendent claimed his capital outlay budget had been cut from $100,000 a year to nothing. As a result, certain programs were becoming obsolete, particularly the machine shop. A further problem that these schools face is increased competition with local high schools for students as a result of declining enrollment. In the past the showcase regional vocational-technical schools had waiting lists of prospective students, but increasingly they are engaged in an "outright war over bodies" with their member districts' high schools.

Students in the vocational and industrial arts programs are moderately responsive to career opportunities in the high technology sector. Computer-related courses are popular at all schools. Electronics is heavily subscribed at vocational schools but is not unusually popular in high school industrial arts programs. A 1980 statewide study by Christine LeCam for the state's Department of Manpower Development concluded that enrollment trends show that this sector of education is responding to the needs of the high technology sector.[34] According to LeCam, secondary enrollments in vocational programs, which make up approximately 82 percent of total vocational education enrollments in the state, have been shifting in the direction of high technology courses such as computer-related business and office programs and electronics assembly and technician training. Between 1972 and 1979, there was more than a 110 percent increase in enrollments in high technology-related occupations at a time when total vocational educational enrollments rose only 50 percent. About ten percent of vocational students were enrolled

in high technology programs in 1979, up from seven percent in 1972. Thus, at a time when students are gravitating toward training in high technology fields, there is an erosion of staff and facilities needed to provide high quality programs.

Industry-Education Relations

Relations between the high technology companies in the Route 128 area and the local public schools, never strong to begin with, are currently strained. Public school administrators and teachers, particularly those who are politically knowledgeable, are angry at the support that the Massachusetts High Technology Council gave to Proposition 2½ in 1980. Indeed, approximately half the companies in the Council donated a total of $229,000 to the Proposition 2½ campaign, 60 percent of the total amount spent on behalf of its passage.[35] Council officials acknowledge that without their last minute fundraising, the measure would not have passed.[36] Industry officials believed that high taxes were a barrier to the recruitment of desperately needed engineers to the Boston area and they supported Proposition 2½ mainly for this reason. They were not intent on reducing resources for education, believing instead that budget cuts would only eliminate waste and inefficiency at the local level.

Resentment among educators against the High Technology Council's support for Proposition 2½ still remains high, especially those in districts that have experienced significant cuts in their budgets. The educators who were interviewed commented:

"Around here high tech is a nasty word" (a science department chair);

"I have a terrible hatred for high tech," (a mathematics department chair);

"I won't sit in the same room with those people" (an assistant superintendent);

"High tech people are not sensitive to morale issues of teachers. They should teach here for a week and then talk about morale" (superintendent of a regional vocational-technical high school).

One industry leader acknowledged that the High Technology Council had a "black knight image" and had done little to ward-off the backlash.

Only two of the public school staff interviewed had supported Proposition 2½. Officials in the one town whose budget was unaffected by Proposition 2½ expressed little resentment against high technology companies, but they were clearly the exception.

The attitudes of the high technology officials interviewed were worlds apart from those educators when it came to assessments of the impact of Proposition 2½ on the public schools. Three-fourths of the managers expressed the view that the budget cuts would fall only on peripheral programs ("mystery novel" courses) and would not have an impact on core academic courses such as mathematics and science. Most felt that if academic programs were cut, it would be the result of politically motivated mismanagement and not due to real fiscal shortfalls. A minority believed that the budget reductions would harm solid academic programs, a process that they claimed would ultimately cause Proposition 2½ to backfire on industry. Several bemoaned the losses of music and the arts, not only for their intrinsic value but also because they saw a correlation between music and interest in software engineering.

In addition to the issue of Proposition 2½, the degree of general mutual disregard existing between industry officials and educators forms another barrier between the two institutions. Like employers everywhere in the country, high technology executives believe that schools are not doing a particularly good job in training students in basic subject areas. Although educators accuse industry of wanting to turn their schools into narrow technical trade institutes, what employers want first is students who have thorough grounding in writing, reading, mathematics, science, problem solving and critical thinking. Despite their misgivings about current academic performance standards and school curricula, however, the managers interviewed believed that suburban Boston schools were relatively effective compared to those elsewhere in the country. They singled out the Boston schools as especially poor. Interestingly, their attitudes toward the quality of schools were more positive than the feelings Silicon Valley employers expressed about the California schools.

Corporate criticism of the schools centered on beliefs that low

academic standards and expectations produced mediocrity. Many managers felt that "excellence" had been sacrificed in the effort to reach children of all ability levels and backgrounds. They also criticized guidance counsellors' lack of awareness of employment markets, teachers unions' rigidity in resisting alterations in personnel policies and work schedules, and school administrators' lack of management skills. Their solutions to educational problems included more merit pay for teachers, the abolition of tenure, differential salary schedules in order to attract mathematics and science teachers, better school management, and the creation of scientifically and technically oriented magnet schools. They generally believed that deficiencies in public schools were brought on by poor management rather than by inadequate funding. Most corporate officials, like their counterparts in California, believed that more money would not necessarily lead to better education. And they were not sympathetic to the plight of laid off school teachers since layoffs are such an accepted part of the American corporate environment. Again, however, it should be stressed that these officials' criticisms of schools were tempered by a general feeling of respect for many of the suburban school systems. Expressions of outright contempt toward the schools, which characterized some of the comments of Silicon Valley executives, were absent.

Educators' criticisms of the companies focused mainly on the issue of their support of Proposition 2½. Over and over, they repeated that they could not understand why firms, which depended on an educated labor force, would support a measure the school people saw as detrimental to public education. "I can't understand their attitude," said the chair of a science department. "Businessmen know money is what makes things happen. You have to invest in a saleable product. I don't know what those people want." Many believed that the firms must not have realized what the ramifications of Proposition 2½ would be when they supported it. And the great majority claimed that the Massachusetts High Technology Council would come to regret its actions. Several school administrators argued that company officials do not understand the importance of teachers' morale in the educational process. "Morale is crucial when you can't turn your heat on until December 1st because your pay is so low," commented one assistant

superintendent. "2½'s symbolism is what is important," he added. "It tells teachers they're bad and they don't get their allowance."

Other issues emerged in the interviews as well. Like educators in Silicon Valley, school officials were aware than industry people held them in low regard. "From their perspective, we only graduate functional illiterates," complained one administrator. Another assistant superintendent commented that "educators are tired of hearing how wonderful the job opportunities are and how lousy the kids are." Other views which surfaced included complaints that reflect longstanding criticisms of industry by school people: industry's perspective is too short-sighted and too self-interested; companies are only concerned with immediate profits and not long term social concerns; and firms' involvements in education usually come with strings attached.

Despite this litany of objections to perceived corporate attitudes and policies, most educators interviewed expressed an interest and willingness to develop collaborative relationships with local high technology firms. Schools' interests ranged beyond traditional kinds of corporate involvement such as plant tours, guest speakers and participation on vocational advisory boards. Several wanted curriculum advice, especially in computer-related areas, summer or sabbatical jobs for science and math teachers, loaned faculty members from industry, scholarships for math and science teacher trainees, gifts of equipment, work experience placement for students, and broad political support for public education.

There are significant pockets of collaboration between high technology companies and some school systems in the Boston area, but companies admit that when they do choose to become involved with educational institutions, they prefer to invest their time and money in university computer science and engineering programs. And even small industry-education projects take a long time to get off the ground. ("It takes several meetings to get a $45 bus for a field trip," complained one vocational educator.) Both companies and schools lack personnel who can devote large blocks of time to industry-education relations, particularly since the onset of the recession in the private sector and budget reductions in the public sector.

School officials are unsure whom to approach in a company ("it is a mysterious process") and claim that contacts are piecemeal and happenstance, often dependent on a personal connection. Few mechanisms have been set up by third party groups to foster ties between the two institutions. High turnover of personnel in these dynamic companies also hinders the development of long-term collaborative efforts. "It's hard to relate to a body rotating through a position," lamented one school administrator. Furthermore, managers in firms who do take an active interest in educational programs with the public schools are usually only marginally influential in their own company. They are not in a position to commit company resources to promising programs. Most school-corporate attempts at cooperative relationships are "still at the talking stage" and many founder as a result of mutual lack of follow-through.

Nevertheless, some industry-education programs at the secondary level have been successful. The most common kind of collaboration exists as a result of state-mandated employer advisory boards for vocational curricula. Most of the vocational educators in the systems studied felt that those boards were useful. One school system also had an advisory board of members of local industry which met twice a year to discuss the system's computer curriculum. That same system had an employee from a local computer consulting firm teach an after-school advanced programming class at a reduced rate. Prime Computer had helped with the electronics curriculum there also. Student co-operative placements were common with high technology companies at one of the regional vocational schools studied.

One of the comprehensive high schools had viable relationships with several high technology companies through the occupational education director and a project of EdCo (a non-profit educational collaborative operating on external grants) located in the school. The school had worked with Computervision, Millipore and the Massachusetts High Technology Council on career awareness programs for students and teachers; six or seven companies had helped the school develop a curriculum for a federally funded electronics assembly program; other companies had assisted in developing a more advanced electronics course; and the school is a member of the Greater Boston High

Technology Forum, a collaborative focusing on career awareness and curriculum development set up by the High Technology Council in conjunction with a regional center of the State Department of Education. The occupational education director at this school, who devotes substantial amounts of time and effort to developing ties with industry, was able to build such ties by being persistent in finding the right person to contact in a company and by becoming involved in any relevant industry-education collaborative he heard about. He felt that if one does find the right company contacts, "many industry people will give of their own time and good things happen."

Only one of the sixteen mathematics and science departments studied for this report had solid contacts with high technology companies. One science department had recently received a $4000 gift of new glassware from Mobil-Tyco, gifted and talented seniors were occasionally placed in unpaid internships at Data General and Mobil-Tyco, and GTE Sylvania had just begun a program of hiring science teachers during a sabbatical year or during the summer.

In addition to the collaborative programs noted in the schools studied, there are other efforts elsewhere in the Boston area. The Massachusetts High Technology Council, largely through the efforts of its human resources consultant, B. J. Rudman, has spearheaded some initiatives. High Technology Forums, which bring together educators and industry people to work on career awareness and some curriculum help, have been organized in several regions of the state. The Council has also helped write the curriculum and served in an advisory capacity for state-funded computer programming courses for laid off school teachers. Raytheon Data Systems in Norwood has for four years run the highly successful "Project Access" involving several hundred students in four local school districts. The company helps train students in routine coding tasks of software programming and then hires them as paid interns and part-time workers. Eventually, some graduates will be hired full-time by the company. A representative of Wang Labs is on the steering committee planning a high technology magnet school in Lowell. Analog Devices, Codex and The Foxboro Company are active in the Business Education Collaborative (BEC) begun in 1980 with several local school systems which focuses on career awareness and curriculum development.

Polaroid, long considered one of the more philanthropically-oriented high technology firms, gives numerous small grants to many kinds of schools, including day care centers, through the Polaroid Foundation.

It is widely acknowledged that Digital Equipment Corporation (DEC), the third largest high technology employer in the state (24,000 workers) behind Raytheon and General Electric, is the leader when it comes to industry-education relations. DEC's reputation is something like that of Hewlett-Packard's in Silicon Valley. The company is involved in a range of programs: scholarships for students; donations of equipment to schools; help with curriculum development, particularly in the area of computer literacy, at schools near DEC plants; and loaned personnel. DEC has contributed $500,000 worth of equipment to the Humbert Humphrey Occupational Resource Center in Boston and has loaned a person to put in substantial amounts of time on curriculum development there.

More recently, there has been a slowly developing awareness among some corporate officials that a crisis exists in pre-college mathematics and science programs. Robert Henderson, the Chief Exective Officer of Itek Corporation in Lexington, has been the leader among New England business people in articulating this issue. And there are indications that new cooperative initiatives are about to emerge connecting high technology firms to schools under the auspices of the Greater Boston and Northeast Regional Centers of the State Department of Education. However, in contrast to issues surrounding engineering education, no industry-education consensus has yet crystallized on the nature of the secondary school problem and its solutions.

There has been a good deal of talk in recent months by national and local political leaders, including President Reagan, about "shared responsibility" and a "new partnership" between schools and industry in order to cope with public budget shortfalls. Schools and social agencies are expected to turn for help to the private sector now that government support is diminishing. This notion, however, ignores the substantial barriers that exist between industry and educational institutions. These barriers are generally more numerous in new, high growth companies than

in mature firms. Aside from those already discussed, several major obstacles stand in the way of long-term collaborative relationships. First of all, the very dynamism, innovation and rapid growth which characterize most high technology firms undermines attempts at extra-institutional ties. These companies, many of whom have growth rates exceeding 30 percent a year, operate in a competitive environment under the intense pressure to get new products into the market. One company studied, for example, develops a new product every 12 working days. The firms need their cash to put back into research and development and need to focus their energy on the central task of the company. Outreach to schools in this context, except by large older companies like Raytheon, is of rather peripheral concern.

Moreover, rapid technological change, the newness of many companies, frequent changes in company organization (mergers, spinoffs, etc.), the unpredictability of workforce needs, and the ever-present vicissitudes of the market lead to short-term planning cycles. This present-oriented planning perspective contrasts sharply with the stability of the schools which tend to operate on five-year planning cycles. Such different temporal perspectives inhibit the development of viable ties between high technology industry and education. In addition, it is difficult for institutions at such different points in their history to interact productively: schools are declining in enrollment, test scores, and financial support, while high technology firms are the current success story of the American economy. With one institution on the upswing and the other "in a dismantling mode," as one educator put it, it is hardly an atmosphere conducive to harmonious relations.

School officials generally see additional government financial aid as a solution to major educational problems. Congressional passage of the National Defense Education Act and the substantial programs of the National Science Foundation in the late 1950s provided significant support for public education when it was apparent there was a crisis in science and mathematics education. Once again, educators feels they need such federal and state funds to finance revitalization of those

subject areas. Yet the conservative "small government" philosophy of business causes them to oppose new government spending programs in domestic areas. It is not likely that industry will provide broad political support for greater educational spending by government until the situation dramatically worsens. Believing that better management and not more money is the solution, business will probably confine their support to a fairly small percentage of companies helping specific schools with special programs. And for those companies that do choose to plow some resources into secondary schools, they face the problem of choosing an effective intervention strategy. Unlike engineering schools where specific problems are obvious and where corporate efforts can make an immediate difference, public schools are large amorphous institutions that are relatively impervious to change from small-scale intervention programs.

To conclude, public schools in Massachusetts, which until now have been fairly strong compared to other states, are in a state of decline. Even suburban schools located in the heartland of the high technology belt on Boston's Route 128 are experiencing a deterioration in the teaching environment. At a point when industry stands at the threshhold of a new microelectronics era, schools look back to an earlier time as their golden age.

II. TWO YEAR POST-SECONDARY SCHOOLS

While Massachusetts has historically been generous in its commitment to public elementary and secondary education, the opposite is true when it comes to public higher education. Enrollment in private institutions of higher education has always been high in New England, 49 percent now compared to 22 percent nationwide.[1] Massachusetts ranks 44th among the states (and District of Columbia) in its percentage of full-time students who are enrolled in institutions of public higher education. This emphasis on private education is one reason why state funding for public higher education is so low. The most recent figures available show that Massachusetts ranks 34th among the states in its appropriations per student, spending about $1000 less per pupil than the national average. And it ranks 51st in the percentage of state tax revenue it spends on higher education.

The sitution in California contrasts dramatically with that of Massachusetts. While California ranks near the bottom in its effort to fund public schools (K-12), it is fourth in appropriations per public college student and tenth in its percentage of tax revenues devoted to public higher education. It is third among the states in its percentage of people enrolled in public higher education.[2]

Massachusetts also varies from the national average in its mix of public student enrollments by type of institution. A smaller percentage of students enrolled in public higher education in the Bay State attend community colleges, 25 percent, compared to 36 percent nationally and 52 percent in California.[3] The Massachusetts community college system, which has only been developed in the last two decades, has been notoriously underfunded. Faculty salaries, which average approximately $19,000, are below national norms for community college compensation. Salaries of community college faculty in Silicon Valley average between $25,000 and $30,000. The fifteen schools have comparatively small enrollments and some have shockingly inadequate physical plants. The "campus" of Boston's Roxbury Community College, housed in a condemned nursing home, and that of Middlesex Community College on Route 128, located in a Veteran's Hospital,

stand in stark contrast to the beautiful and well-funded community colleges in and around Silicon Valley. Approximately 7,000 day and part-time evening students are served by Boston's two community colleges compared to more than 24,000 students in San Jose, California, a city roughly the same size as Boston. The community colleges have played a major role in California's economic development both in training new workers for industry and in re-training older employees. But because community colleges have been so small and ill-equipped in Massachusetts, profit-making proprietary schools and other education and training institutions (Wentworth Institute of Technology, the two year programs of Northeastern University, CETA programs, secondary vocational-technical schools, company in-house training) have played a more important role in vocational education. For example, Sylvania Technical Institute, a proprietary school, has long been the major source of newly trained electronics technicians in the Boston area whereas the bulk of such training in Silicon Valley is done in public, tuition-free community colleges.

Community College administrators have learned to run courses on a shoestring. Lacking money from their regular budgets, they often offer courses on a revenue-generating continuing education basis. And most of the money used to start up new technologically-oriented programs in the last few years has come from federal occupational education funds administered by the State Department of Education. These funds, however, are diminishing as a result of federal budget cutbacks. Several of the colleges in the Boston area are having to turn away students because of inadequate space or lack of permanent faculty. For example, Massachusetts Bay Community College accepts only one of every three students who apply and Roxbury, Bunker Hill and Middlesex Community Colleges are oversubscribed.

Enrollments in High Technology Programs

All of the post-secondary training sources in the Boston Area are expanding programs and course offerings in fields relevant to high technology. Wentworth Institute of Technology, long regarded as a source of well-trained technicians, is planning to double its enrollments to 5,000 students in the next four years. Sylvania Tech expanded its electronics technician training by one third in 1979 so that it now trains about 2000 students a year in its nine month program.

Control Data Institute, a proprietary school preparing students to be computer programmers, computer technicians and operators, grew by one third in 1981. Blue Hills Technical Institute, a public two year institution with 560 students has experienced a significant upsurge of student enrollments in its electronic technician and computer programming associate's degree programs even though its tuition was raised from $500 to $2000 after the passage of Proposition 2½. The fifteen community colleges have more than doubled their enrollments and degrees awarded in technology-related programs (mostly in computer programming, data processing, electronic technology and engineering transfer programs) since 1976 (Tables 2.1 and 2.2). And the disbursement of federal occupational education funds administered by the state to secondary and post-secondary schools has shifted in the direction of funding programs in high technology areas in the last few years.

All of the five Boston area community colleges studied in this project reported increased enrollments in electronics courses and even greater increases in computer-oriented programs. Several schools, particularly Northern Essex, Bunker Hill, and Middlesex have made a concerted effort to develop new programs in high technology areas. Middlesex, for example, has courses to train ultrasound technicians, electronics technicians, electro-mechanical drafters, radiologic technicians, computer operators and people in technical writing software. It also has a number of small short courses of study in fields such as word processing run through Continuing Education or the Community Service programs. Bunker Hill and Northern Essex offer programs to train technicians and have courses in various data processing technologies. Northern Essex has 550 night students using the electronics and other technical equipment at the Greater Lawrence Vocational-Technical School, one of the few good examples of a community college degree program that has linked up with the better-equipped facilities of the vocational-technical schools. Northern Essex has become particularly adept at securing external funds from a variety of sources, including CETA, in order to develop new programs. Massachusetts Bay, new to the development of technology-related courses, now offers a popular computer science major, training for test technicians, and a word processing program. Roxbury offers

Table 2.1

Massachusetts Community College Enrollment Per Year for Engineering Related Programs, 1976-1982

Year	Electronic/Computer* Technology	Engineering-Transfer Programs	All Others	Total
1976-1977	459	352	1,251	2,062
1978-1979	559	460	1,228	2,247
1980-1981	929	672	2,193	3,794
1981-1982	1,182	741	2,309	4,232

*Includes: Electronic Technology
Computer Maintenance
Electro-Mechanical Technology
Instrumentation

Source: Massachusetts Board of Regents of Higher Education

Table 2.2

Associate Degrees Awarded in Technology-Related Fields Massachusetts Community Colleges, 1977-1981

Year	Mechanical and Engineering Technologies	Data-Processing Technologies	Total
1977	293	134	427
1978	499	158	657
1979	477	176	653
1980	479	275	754
1981	541	380	921

Source: Massachusetts Board of Regents of Higher Education

a program in electro-mechanical drafting and has a sprinkling of other technical courses. It has long range plans, in part dependent on the building of a long-promised new campus, to link up in a major way with the facilities of Boston's Hubert Humphrey Occupational Resource Center for some occupational education programs.

Given the fiscal constraints of all of the community colleges and the limits placed on some of them by their inadequate physical plants, it is remarkable that the schools have been able to respond to the market for technical training as well as they have. Some feel, in fact, that they are training beyond their capacity as students line up for a limited amount of time on computer terminals. The effects of chronic underfunding are apparent at all of these schools. The Roxbury Community College facility is totally unsuited for technical course offerings, and the college is forced to offer mostly liberal arts classes. Moreover, since its founding in 1973, the College has not received a single penny for capital expenditures. Though this scandalous treatment is not repeated to the same degree elsewhere, other colleges have similar complaints. All claim they have difficulty in hiring technical instructors at $15,000 to $17,000 salaries. As a result, many rely on hiring retirees. And all report critical understaffing, one result of which is a lack of personnel to develop cooperative programs and to seek donations from industry. One school was relying on two inexperienced volunteers to approach industry. Another school had to turn away 600 students from computer courses in one year because of a shortage of faculty. Some programs, such as microwave technician training, cannot be offered because the equipment is too expensive to purchase, and because companies have not volunteered the use of their own equipment for colleges' training purposes.

The impact of underfunding is dramatically illustrated by the plight of one small, new electronics technician training program at one of the schools. Because there is no money to hire more than two permanent faculty, the course of study cannot be expanded to a full two year degree program. There is no laboratory assistant and there is no money for service contracts for repairing equipment. For a year and a half, the program director, who has many other responsibilities, was without even a telephone for making calls outside the college. Not suprisingly, an employer advisory board for the electronics program has never been established. According to the administrator,

"I shouldn't be running this program. I don't know anything about electronics and computers. I can't talk about it intelligently with other people in the field." As the interview was being conducted, his office had to be vacated due to flooding from a rainstorm. Contrast this with information in a letter received by the researcher in the fall, 1981, from the director of an electronics technology program at a community college in California. "Our electronics program has now grown to ten full time instructors and we will hire two more next fall. Even with this expansion, we had to turn away more than 1000 students each of the last two semesters." The capacity of the California community colleges to have large, high quality programs far outstrips that of Massachusetts.

Relations with High Technology Industry

As with public secondary schools, there are pockets of constructive relationships between the community colleges and high technology firms. Some of the schools have been involved in contract courses with a specific company whereby the college provides the upgrading training of some employees. For example, Northern Essex has provided such training for Gould-Modicon, Western Electric, Compugraphic and Varian, and Middlesex Community College has provided similar services to Honeywell, Western Electric and Digital Equipment Corporation. Bunker Hill has conducted training programs for technical workers with Honeywell Information Systems. Wentworth Institute, the oldest (founded in 1904) and largest (approximately 3000 students) of the non-proprietary private two year technical schools in the area, has conducted many such courses over the years. Seven of the community colleges, in cooperation with member firms of the Massachusetts High Technology Council, were also recently involved in CETA training programs in electronics technology. Middlesex Community College conducted a successful five month technical writing software program for laid-off school teachers. It was partially funded by federal occupational education funds and curriculum and instructional help from high technology companies, particularly Data General, Honeywell and Digital Equipment.

The state-funded Bay State Skills Corporation has also brought together several community colleges and high technology companies in joint training efforts. The Corporation was the brainchild of George Kariotis, Governor Edward

King's Secretary of Economic Affairs and a former high technology executive himself. The state legislature set up the Corporation in 1981 and gave it $3 million dollars over a two year period, to be matched by industry funds, to develop programs in high growth fields. The hope was that educational institutions at all levels would plan courses of study and then approach companies for students and matching aid. The effort has met with mixed success. Dozens of programs have been funded such as one in which Bunker Hill Community College provided training to upgrade assemblers already on the job at Data Printer Coporation. Another matched Roxbury Community College and Stone & Webster in an entry-level training program for electro-mechanical drafters. However, some schools have been slow to develop proposals and many companies have been reluctant to come up with cash. Many firms shy away from any program funded through a government agency. Schools sometimes have difficulty gearing up on short-term notice for one-shot programs. Response to the Corporation, however, has been more positive among both industry and education people than a similar but more bureaucratically-encumbered effort (CWETA) in California.

A number of the colleges have active industry advisory boards, some of which work well and some of which do not. A common complaint among community college officials was the lack of money to hire staff who could nurture those advisory relationships. Most of the two-year schools have at least one member from high technology firms on their Boards of Trustees. But few companies have donated equipment or have given other kinds of contributions to the community colleges. A major exception to this is the recent $3 million gift of new computer equipment by Wang Labs to each of the state's public institutions of higher education. All of the recipients have acknowledged that the gift will be a significant addition to their facilities. Digital Equipment donated loaned personnel and equipment to Roxbury Community College and Middlesex Community College. And the Massachusetts High Technology Council designed an electronics curriculum guide for technician training programs. Overall, however, firms have donated fewer resources to the community colleges than their corporate counterparts have in Silicon Valley. And the Boston area schools have been less likely to provide on-site training for the companies.

The corporate managers and political leaders interviewed generally believed that the Massachusetts community colleges were making a real effort to respond to the workforce needs of the high technology sector. Most realized that the colleges were operating with less than adequate facilities and budgets. Many claimed that of all sectors of education, the community colleges were most responsive to industrial shifts. They usually added, however, that there were several colleges which have done little in the way of technology-oriented education. The one school that does specialize in technical training, Springfield Technical Community College, is located outside the belt of high technology companies. Industry leaders who are familiar with the problems of community colleges recognize that the schools need more money in order to offer a range of programs that are congruent with market needs. And all observers agree that the community colleges in Massachusetts have a status lower than that of similar institutions in other states, particularly California.

Community college officials for their part expressed eagerness to offer programs that would prepare students for jobs in high growth companies. They felt that such jobs represented the wave of the future and believed a share of the school's resources should be committed to technical training. Only one college administrator expressed reluctance about jumping on the high technology bandwagon: "I am always fighting attempts to make this a technical institute. We want to leave some room for the liberal arts." School officials believed that they had the capacity to be flexible in the length and content of course programs and could add on new programs through the self-supporting mechanism of continuing education, an enterprise enrolling approximately 50,000 students across the state. But with reductions in federal occupational education money and CETA funds, the outlook for growth from other external funding sources seems bleaker than before.

High Technology Influence on the Board of Regents

One issue that has come up repeatedly in the mass media and in meetings of faculty, students and other public college officials is whether or not the newly-appointed Massachusetts Board of Regents of Higher Education is "controlled" by high technology exectives. The Boston Globe referred to the "high tech

entrepreneurs who now dominate the state Board of Regents" in an editorial entitled "High tech's higher ed" (February 15, 1982). Another article cited observers' worry that the "curriculum is being skewed to turn out qualified employees for high tech jobs at the expense of other disciplines" (September 27, 1981). A piece in the Boston Phoenix was entitled "Just married: the high tech/higher education honeymoon" (April 28, 1981). Of the fifteen members of the Board of Regents, all appointees of Governor Edward King, three are from high technology firms: David Beaubien, Vice President of EG and G, Ray Stata, Chief Executive Officer of Analog Devices and founder of the Massachusetts High Technology Council; and An Wang, founder of Wang Laboratories.

Debates about the future direction of the curriculum in public higher education generally run to one of two extremes: one view paints public higher education, especially its tenured faculty members, as insensitive and unwilling to change curricular directions to meet market forces; the other view holds that there is a coordinated effort by high technology firms, through their members of the Board of Regents, to turn the colleges and universities into a"training ground for Dr. Wang." Indeed, as an example of the latter view, one community college administrator interviewed said "I resent governors who make college presidents turn institutions over to industry to train cogs in the wheel of American industry." But the great majority of public college administrators interviewed believed that while the high technology industry executives on the Board had more influence than others, they did not "control" the Board. All agreed that the influence of the high tech regents on Governor King was crucial in getting the Governor to recommend a 10 percent increase in the 1982-1983 budget for public higher education. Since the proposed budget increase was meant to cover faculty salary increases as well as the expansion or development of technology and health-related programs, administrators did not see the executives' support as being totally self-interested. Almost all favored the presence of high tech people on the Board because they believed they would become influential and forceful advocates of public higher education. They also were nearly unanimous in pointing out that after their appointments as regents, the executives had educated themselves about both the real budgetary problems of the schools and the schools' capacities to run solid programs.

The extremes of this debate show that, at times, "business and education are critical to one another without good foundation for their position," in the words of one high technology regent. For example, contrary to what many business people think, college enrollments in elementary and secondary education have been dropping since the mid-1970s. A look at other enrollment figures in community college programs and those of public colleges and universities show that there have been many significant changes in students' curriculum choices in the last few years. The charge the Massachusetts public colleges and universities are being transformed into technical training institutes is also ill-founded. In fact, the system until recently has had few technical training programs available to students, forcing them to attend more expensive private schools or proprietary schools if they wanted such training. The public engineering programs, for example, which students take for granted in midwestern and western states, have been in short supply in New England. While San Jose State University offers a full range of engineering majors to hundreds of students in Silicon Valley at a very low cost to the students, citizens who live in Boston have no local public engineering school. The Massachusetts state colleges have been particularly lacking in technology-oriented offerings. Such programs at community colleges are still relatively new and small. Thus, what is happening is an attempt by the Regents to build some balance into a system that has long denied many of its students access to programs that would lead to good jobs. Moreover, it should be pointed out that Regent David Beaubien is considered an advocate of a broad liberal arts education and even Ray Stata, the leading spokesperson for high technology industry in Massachusetts, speaks of the need for technical education to increase the humanistic content of its required courses.[4] Stata also was singled out by many of the educators interviewed as being particularly well-informed and attentive to the problems of individual schools, although they also were quick to add that his long-range social vision was atypical of business leaders.

Barriers to Industry-Education Cooperation

Although community colleges are generally willing to adjust their

curricular offerings to fit employment opportunities in high growth areas and administrators have positive feelings about the high technology Regents, a number of strains between the companies and the schools exist nonetheless. The community college people feel they get very little from the companies in any way. They believe, correctly so, that corporate concern is focused on engineering and four year computer science programs. Some dislike what they perceive as the arrogance of companies when they are approached by education ("they see us as failing") and noted that when schools contract to provide a course for campanies there is a built-in domination by the private firm. One continuing education director was concerned that such contract courses had to stay off certain controversial topics such as health hazards on the job or labor union activities or were steered away from broader theoretical training that would give an employee more flexibility. His concerns were echoed by a corporate manager who felt for these same reasons that schools should be careful to maintain their independence in on-site contract courses.

Other barriers were cited. Company turnover was a problem for some. In one employee upgrading program taught on-site at a company by a community college, the firm's coordinator changed three times in one year. "We might as well pencil on their names," complained the electronics instructor. However, complaints about corporate turnover were not as numerous or intense as those of Silicon Valley educators. Most of the community college administrators believed that the firms were not generally interested in using their services to upgrade their employees. "Once a company hires a training director, all is lost," lamented one administrator. Others cited the difficulties in finding the right person to approach in a firm. The sporadic nature of company workforce needs also created problems for administrators trying to plan programs. Thus, overall, the two year schools felt that the great majority of high technology firms in the area were not interested in collaborative relationships with them at the moment and had little commitment to helping them with donations of money, equipment or personnel. It is possible that more cooperative training programs will evolve in the future as mediating third party groups such as the Bay State Skills Corporation or the Council for Northeast Economic Action become more active in matching up schools with firms.

A Note on Workforce Projections

Government and industry forecasts have been projecting an increased need for a variety of skilled technicians in high growth areas such as the health and electronics industries. A troublesome issue which emerged from the interviews, however, was the question of whether or not there was a shortage of electronics technicians of various kinds (e.g., manufacturing test technicians, field service technicians, computer maintenance technicians). Every type of training institution--private, proprietary, CETA, and public colleges--has experienced some difficulty in placing their technician graduates in jobs during 1981-82. The problem is not severe, (Sylvania Tech said its graduates now had only one or two job offers rather than the five or six they had in previous years), but enough slack in hiring exists to make school administrators nervous. This is especially true for those institutions who have expanded their training significantly or are in the process of doing so. Christine LeCam's 1980 study for the Massachusetts Department of Manpower Development also questioned the need for increasing the supply of newly trained technicians.[5]

Executives at several companies said they did not anticipate either a short-term or long-term demand for technicians, especially manufacturing test technicians, and cautioned that educational administrators should not expand programs too quickly. They felt that schools should aim for small programs of high quality. A human resources manager with recent experience in two companies pointed out that there has been a dramatic drop in the need for electronics technicians in those firms in the last year. At the same time, other high technology companies claim they have a continuing demand for technicians.

Obviously, the current economic recession is a major reason for the recent softness in the market for electronics technicians. Changes in technology have altered the work of technicians in some companies. For example, the products of one minicomputer company are increasingly manufactured with "built-in diagnostics" that inform a field service technician what is malfunctioning. Instead of determining what is wrong with that self-identified circuit board, the technican simply replaces the whole board. These "built-in

diagnostics" and the policy of "board swapping" has the result of reducing the skill level needed in the technician's job. "Advance maintainability," building products in a way that they can easily be repaired, is becoming more common. Since almost half of all technicians work on repair of some kind, these technological changes have important implications for that occupation. Companies vary in the degree to which they have de-skilled technician's work. Even among firms manufacturing the same product, there are differences in how far they have proceeded in these and other technological changes. Hence, employment projections for technicians can vary substantially.

At the same time there are countervailing trends which argue for both greater numbers of technicians and high skill levels among them. Applications of computers to various areas of human activity are just beginning to occur, and many of those applications will require technicians to help develop and maintain them. Products are becoming more complicated and a certain percentage of technicians will have to understand the way they operate. There is also some awareness among executives that many tasks which engineers perform could be farmed out to skilled technicians, thus alleviating the engineering shortage. At the same time, of course, the demand for technicians would increase. External political forces will make a difference: the Economics Department of the First National Bank of Boston has warned that the newly proposed defense program of President Ronald Reagan could exacerbate critical labor shortages. Should large defense contracts come through in New England, there will be stepped up demand for electronics technicians.[6]

Some of the same questions have been raised in the area of entry level training for computer programmers who are in less than a four year computer science program. Again, there is widespread agreement among trainers that in the Boston region at the moment people trained in fairly short-term programs are having some difficulty finding their first job. When they are hired, it is usually with a "user" firm (a bank, an insurance company) and not with a high technology manufacturer. Entry level technical writing jobs are not plentiful at the moment either. This mixed picture makes it difficult for educational administrators at various levels of training to make decisions about the allocation of resources to training programs. It is clear that

educators need to keep in regular touch with a representative sample of employers, especially in the area of test technician training. It would be unfortunate if Massachusetts began to produce an over-supply of entry-level technicians as is now happening in Colorado.[7]

To conclude, the importance of community colleges and other one-to-two year post-secondary educational and training institutions to the region's economic development cannot be exaggerated. Graduates of these programs tend to remain in the area, and the resources of these facilities can be used not only for educating young people but also for the re-training of adult workers as technological changes alter work requirements. But as yet, the two year schools in Massachusetts have not received the attention and resources that have been more richly bestowed on their counterpart institutions in many other states.

III. FOUR YEAR COLLEGES AND UNIVERSITIES

High technology industry leaders have been very vocal in recent years about the shortage of newly-trained engineers and computer scientists at the university level. The California-based American Electronics Association and the Massachusetts High Technology Council have publicized their members companies' future employment forecasts which show a significant shortfall of trained personnel.[1] The mass media has had numerous articles on the promising job opportunities for engineers, especially electrical engineers, and college trained computer science graduates. Business people have been critical of the private and public colleges for not having programs of sufficient quantity and quality in these fields, although those criticisms have become muted in the last year as student engineering and computer science enrollments swell and as corporate leaders become aware of the fiscal constraints which limit the ability of the four-year schools to respond to market forces.

New England has long been known as a center for higher education. Billed as "the most knowledge-intensive region in the world," the region has 260 colleges and universities educating 800,000 students, 25 percent of whom migrate to the area from other parts of the country. New England has the greatest number of institutions of higher education per capita of any region in the country.[2] The view that New England's major resource is its educated labor force has received a good deal of attention recently, most notably from the New England Board of Higher Education which has issued several recent publications on the subject.[3] Political, educational and industry leaders have been stressing that since the strength of the economy is based on a well-educated pool of labor, it is essential that colleges and universities not only maintain strong programs in traditional liberal arts fields but also expand, upgrade and develop technology-oriented fields of study. Many states across the country, urged on by their governors, are scrambling to reorient higher education in a more technical direction in order to retain and attract high technology industry. Increasingly, then, college programs are seen as a tool of regional economic development.

New England's schools already educate a disproportionate share of the nation's engineers according to data assembled by Joan Grebe of the New England Board of Higher Education. Although California educates more engineers at all degree levels than any other state, Massachusetts ranks sixth among the states in awarding undergraduate engineering degrees, third in Master's degrees and fourth in doctoral degrees. The Massachusetts Institute of Technology stands first in the country in awarding engineering doctorates and second in granting master's degrees. Electrical engineering, which accounts for 27 percent of all engineering degrees granted in New England, is the most popular field of male engineering students at every degree level but ranks third among the rapidly growing numbers of female engineering students. About half of New England's students in colleges and universities are enrolled in private institutions, and those schools award two-thirds of all engineering degrees. The proportions are more equal when only undergraduate degrees are considered.[4]

Enrollment Trends

The message conveyed by the mass media that well-paying engineering and computer science jobs are plentiful has not been lost on students. Attentive to the job market, college students across the country have been flocking to majors in these fields. Engineering is now the most popular intended area of study among male high school seniors taking the Scholastic Aptitude Test (Table 3.1). Approximately 22 percent nationally chose engineering, with similar percentages doing so in Massachusetts and California. Only three percent of the females, however, indicated the same. Another seven percent of the males and five percent of the females chose computer science as their intended choice of study. The proportion choosing computer science has tripled since 1975.[5] Undergraduate engineering enrollments, which have historically gone through periods of boom or bust, have been on the upswing since a trough in the mid-1970s. Entering freshmen classes in engineering are now at an all time high and would be much higher if colleges and universities could accommodate the demand.[6] Graduate enrollments are up as well.

Table 3.1

Percentage of 1981 College Seniors Taking SAT Exams Choosing Engineering Or Computer Science As Their Intended Area of College Study, By Region and Sex

	Engineering*		Computer Science/Systems Analysis**	
	Male	Female	Male	Female
National	21.5%	3.2%	6.5%	4.8%
Massachusetts	20.5	2.4	8.9	4.7
California	20.9	3.5	6.4	4.5

**SAT verbal mean: 416
math mean: 492 (national)

*SAT verbal mean: 446
math mean: 534 (national)

Source: "College Bound Seniors, 1981," National, California, Massachusetts, The College Board.

Table 3.2

Full-Time Undergraduates Enrolled in Electrical Engineering and Computer Science at the Three Massachusetts Public Engineering Schools, 1981-82

Year	EE and CS	All Other Engineering Programs
Freshmen	846	883 (est.)
Sophomore	615	767
Junior	561	879
Senior	350	877

Source: Massachusetts Board of Regents of Higher Education.

These national trends are apparent in the Massachusetts schools of engineering and computer science. The number of undergraduates in MIT's School of Engineering more than doubled between 1972 and 1982. Nearly one third of all undergraduates there who have declared a major are in electrical engineering and computer science, and another third are in other engineering fields. MIT's graduate engineering enrollments have grown by about one third in the last ten years also. Current full-time freshmen enrollment in electrical engineering and computer science at the three public Massachusetts universities awarding engineering degrees (University of Massachusetts, Southeastern Massachusetts University and University of Lowell) is more than twice the number of seniors in those fields--846 freshmen compared with only 350 seniors (Table 3.2). The number of master's degrees awarded in these areas has jumped as well although the overall figure in 1980-81 was only 84 graduates (Table 3.3). Over 1000 students are enrolled as computer science majors in the nine state colleges. Boston University has begun a major reorientation of its undergraduate curriculum in the direction of science and engineering. The number of undergraduate students enrolled in engineering (1500), one third of whom are women, has grown rapidly in recent years. Applications to Worcester Polytechnic Institute (WPI) have jumped 28 percent in the last four years. WPI along with Bentley College, Boston College and MIT, is one of the top four schools in Massachusetts in producing bachelor's degree recipients in computer science.[7] Lesley College has led the way in developing graduate programs in the use of computers in schools.

Northeastern University, the second largest producer of engineers in New England after MIT, is establishing a separate College of Computer Science and has received more than 1000 applications in one year for 150 openings in the current program. Enrollments in engineering have increased 30 percent in the last three years, and a dual engineering degree program has been established with Emmanuel College. Northeastern has also developed a range of other new programs to respond to growth in high technology employment: a part-time High Technology Master's in Business Administration program aimed at experienced technical professionals; various kinds of computer technology offerings; technical writing programs;

Table 3.3

Total Number of Electrical Engineering and Computer Science Degrees Granted Per Year By Massachusetts Public Engineering Schools

Year	B.S.	M.S.	Ph.D.
1976-77	172	48	0
1977-78	200	41	5
1978-79	201	51	5
1979-80	205	53	2
1980-81	199	84	6

Source: Massachusetts Board of Regents of Higher Education.

and Women in Engineering and Science initiatives. The President of the University, Kenneth Ryder, was also instrumental in setting up the Bay State Skills Corporation and a consortium of Massachusetts engineering universities which is working on collaborative research and training efforts.

These trends are only a sampling of the alterations in curricula which are occurring in public and private colleges and universities in Massachusetts. From all this it is clear that colleges and universities are responding to shifts in the regional economic environment, although industry may not see these changes as being as rapid or pervasive as they would like. The changes appear to occur not because of the direct influence of high technology employers on university policies but because of students' demands for technologically oriented fields of study.[8] In an era of declining enrollments, colleges have to be responsive to their own market, their students. When students clearly want access to certain kinds of programs, the schools feel they must respond to some extent if for no other reason than their own survival as viable institutions. It is rare that a major curriculum shift is initiated by faculty and administrators prior to a change in student interest.

Obstacles to Expansion of Engineering and Computer Science Programs

Engineering schools and computer science programs across the country have not been able to expand sufficiently to cope with the rising student demand. The most serious problem is the difficulty of attracting faculty because of industry's superior research opportunities and higher pay. Fiscal constraints of the schools, due in part to declining federal support, have led to a deterioration of research and teaching facilities. Class sizes are now larger because of increased student enrollments and a large number of faculty vacancies (1600 positions nationwide in 1981). Research grants are more difficult to obtain. A large majority of engineering schools, according to a recent study conducted for the National Science Foundation, report that the quality of both research and teaching has declined. There is a greater reliance on teaching assistants and adjunct faculty to teach courses and many courses cannot be offered at all.[9]

The pool of doctoral students, the traditional new source of new faculty, has been shrinking. A high percentage of doctoral students are from foreign countries.[10] As a result, almost one fourth of all junior faculty now in engineering departments received their undergraduate training outside of the United States. It is the difficulty of attracting new junior faculty rather than the retention of senior faculty that presents the major problem.[11] An NSF survey of graduate engineering departments showed that six percent of the engineering faculty in these 1500 departments resigned during 1978-79, and only 28 percent of those left in order to take a nonacademic job.[12] Faculty in engineering and computer science average extra earnings each year equal to 38 percent of their academic salaries. While computer science and engineering salaries are higher than those of professors in other disciplines ($27,535 versus $24,834) and though they received pay increases greater than their colleagues in 1981, there has been pressure in many schools and states to place engineering and computer science faculty on a pay scale further above that of other faculty.[13] (That effort has recently been successful at the University of California.) The difficulty of attracting adequate numbers of new faculty and the lack of other resources mean that only one in three qualified engineering undergraduate applicants are accepted into an engineering program.[14]

The Massachusetts engineering and computer science schools have experienced all of these difficulties although the more elite schools, notably MIT, have suffered less than others. Even MIT, however, has had trouble attracting the faculty it needs in some fields. The engineering programs at the publicly-supported universities have been especially hard hit. John Duff, Chancellor of the Massachusetts Board of Regents of Higher Education, estimates it will cost over $7 million during 1982-83 and approximately $2 million each year thereafter for four years if the three Massachusetts universities are to restore and maintain laboratory and computer equipment quality.[15] These figures would be even higher if all qualified applicants were admitted to the programs to the point of saturating the present physical plants. The average SAT math score for entering freshmen in engineering at the public University of Lowell is

635, a highly competitive figure. Lowell needs to hire 13 faculty in electrical engineering just to handle students who are already enrolled there. Duff estimates that there is currently a shortage of 183 engineering faculty at the three Massachusetts state universities.

Salem State College, which had turned away as many as 200 students a semester from computer science courses because of faculty shortages, saw student enrollments in that field rise from 460 to 730 in 1981-82 after they were allowed to hire three new faculty members. The well-regarded computer science program at Framingham State College, which has seen enrollment jump from 266 in 1974-74 to 1048 in 1981-82, has had to limp along with only two full-time faculty and 21 part-time teachers. A graduate program in computer science has been approved at the University of Massachusetts at Boston but insufficient equipment prevents the program from being implemented. There are no research facilities for faculty there, making it difficult to retain and attract professors. Northeastern University has ten faculty vacancies they have not been able to fill. It needs an additional $3.5 million more for equipment purchases and over $1 million more for faculty salary compensation.

Massachusetts students have traditionally depended more on private education than students elsewhere, and as a result plan to spend a good deal more on education than their West Coast counterparts (Table 3.4). But the pressure on public college and university enrollments in engineering and computer science will increase as private tuitions increasingly soar out of reach of middle class families and as federal and other scholarship monies decline. New funds currently being allocated by the state legislature for technology-oriented programs will help the system, but unless these additional appropriations continue for several years, the funds for 1982-83 will only be "a drop in the bucket," in the words of one Regent.

The Industrial Response to the Engineering Education Crisis

Corporations have been much more attentive and responsive to the plight of engineering and computer science education than to the problems of scientific and technical education at the two year colleges and secondary

Table 3.4

Percentages of 1980 Seniors Planning to Attend College and Percentages Estimating Costs of College, By Region

	New England	Pacific
Planning to Attend College or University:		
4-year	52%	43%
2-year or Community College	48	58
Planned Student Status:		
full-time	71%	55%
part-time	29	45
Estimated Annual Expenditures for College:		
none	28%	19%
less than $1,000	21	49
$1,000-2,000	11	14
$2,000-4,000	21	13
Over $4,000	19	6

Source: High School and Beyond, National Center for Education Statistics, 1980.

schools. The facts about university engineering education have been widely publicized not only by educational and professional associations but by corporate groups as well. The American Electronics Association, the Massachusetts High Technology Council and the Semiconductor Industry Association are making major efforts to identify the needs of engineering schools and to encourage business support of various kinds to those institutions.[16] The AEA and MHTC are cooperating in a campaign to get their member companies to donate two percent of their research and development budgets to engineering and computer science education. The Exxon Education Foundation is giving $15 million to 66 colleges and universities for teaching fellowships for engineering doctoral candidates and to 100 departments of engineering and allied fields for salary supplements to junior faculty. Generally speaking, high technology companies have had a poor reputation for giving to educational or charitable concerns, a pattern usually attributed to their relative youth and size. (Small companies with less than 100 employees make up about three quarters of the high techology sector in Massachusetts, although one quarter of all the high technology firms account for 90 percent of employment in the industry.)[17]

A consensus among regional and national industry and educational leaders on the nature of the engineering education problem and some of its solutions has been reached during 1981-82. They agree that engineering schools have critical problems, based fundamentally on inadequate financial resources, and have developed a list of ways in which corporations can come to their aid. The recommendations encourage industry to make donations of cash, equipment, and fellowships to the schools, loan instructional personnel, provide summer jobs and consulting opportunities to faculty, create more co-op placements for students, supplement faculty salaries, establish endowed chairs, and develop collaborative research efforts. The proposals also ask that industry support state legislative action both to upgrade salaries for public university engineering faculty and to increase state budget allocations for engineering and computer science education at these schools.[18]

What is absent from all of these recommendations, however, is a call for significant federal support of engineering education. Industry leaders have instead focused on stepped up corporate and state government contributions to engineering education to solve the problem. The Reagan administration has also put forth the view that universities and industry together, not the federal government, "are best equipped to deal directly with the temporary or cyclical fluctuations in supply and demand." Instead, the federal government should only "provide oversight and help to focus national attention on these problems." [19] George Keyworth, President Reagan's science advisor, recently warned against efforts to deal with scientific and engineering manpower planning in a national, centralized manner. This view, however, is not shared by engineering professional societies and university administrators who argue that the magnitude of the problem is so great, only substantial federal support will ultimately alleviate the crisis.[20]

A few of the larger Massachusetts high techology firms have already been making contributions of various kinds to the state's engineering and computer science schools. Several firms have developed a reputation for generosity in giving--Digital Equipment Corporation, Analog Devices, Data General and Raytheon were mentioned the most frequently by university administrators. Only a few have established foundations--GenRad, Honeywell and Polaroid. (General Electric, sometimes classified as a high technology firm, has long given through its GE Foundation.) MIT is the recipient of corporate largesse more than any other engineering school. As of the fall of 1981, MIT received $18 million annually from corporations for research.[21] Several Massachusetts high technology companies have made gifts to MIT in recent years--e.g., GenRad Corporation, Analog Devices, Digital Equipment, Teradyne, Analogic Corporation, Foxboro Company, Honeywell and Polaroid. Contributions to MIT's planned $21 million Very Large Scale Integration (VLSI) center in Cambridge, however, have come from large corporations based primarily outside Massachusetts.

Despite recent publicity that relations between MIT and Massachusetts high technology companies are strained, MIT has in fact the closest and

most enduring ties with the companies of any school in New England. Many of the firms were founded by MIT graduates, and others spun off from MIT laboratories. MIT faculty are involved as consultants or directors of many companies, and MIT provides the largest number of technical and professional employees to companies of the Massachusetts High Technology Council. The University has an active Industrial Liason Program with over 270 company members (generating close to $6 million in revenue annually to MIT) which provides the firms with access to the Institute's research and staff resources. Other links to industry exist as well: 16 percent of MIT students are in cooperative work-study programs; short courses, including video courses, are offered to industry personnel; a Management of Technology master's degree has been developed jointly between the Sloan School of Management and the School of Engineering; and a small, part-time master's program in the Department of Electrical Engineering and Computer Science has been developed for people already employed in industry. While the size and structure of the latter program fall short of industry desires, it appears to be a first step in what might become a much larger effort to provide continuing education for experienced technical professionals.[22] Thus, like Stanford University and other elite engineering schools, the relationship between high technology industry and MIT is relatively harmonious and close. The two institutions respond relatively well to each other's needs.

While no other college or university enjoys corporate largesse to the extent MIT does, others have received some significant donations from high technology industry. Northeastern University, the second largest provider of technical professionals to companies of the Massachusetts High Technology Council, has been the beneficiary of company contributions from Computervision, Analog Devices, Data General, Digital Equipment, IBM and the General Electric Foundations. Data General played a major role in helping the University of Lowell develop a computer science major by contributing equipment, loaning instructors, and advising on curriculum. Analogic Corporation, Digital Equipment, Analog Devices and Computervision, among others, have also made donations to Lowell. The University of

Massachusetts at Amherst has received major help from Raytheon and Digital Equipment, and has benefitted also from the contributions of Wang Labs, Alpha Industries, Analog Devices and General Electric. Worcester Polytechnic Institute has succeeded in garnering donations of $1.7 million from industry for its research budget and has received donations from Analog Devices, Computervision and Digital, among others. All of these schools provide in-service training for companies' technical professionals on and off company sites. Northeastern's part-time master's program in engineering dwarfs all others in size, enrolling more than half of all part-time graduate engineering students in the state. Northeastern University also has a number of students in its co-op program working in electronics and computer companies. Some of the schools have been linked to industry through advisory boards or through joint programs under the auspices of the Bay State Skills Corporation.

Another emerging area of industry-education collaboration centers on the development of a research and training microelectronics center in the state. At Northeastern's initiative, a consortium of industry, education and government leaders have planned a $40 million center that would train people from engineering and technician-training schools and companies in the design and production of semiconductor devices. The directors of the center would be drawn in equal numbers from industry, education and government. Public funds for the project would be matched by donations of various sorts (equipment, cash and teacher personnel) from high technology companies. It is expected that Digital Equipment will be a major contributor to the center.[23] This proposed center is similar to others being established in other states (e.g., North Carolina, Minnesota, California) as these states compete with one another to retain and attract high technology companies.

Industry and Education: Views of One Another

Massachusetts industry executives interviewed were generally positive in their opinions of the college and university engineering programs in

the state. They also gave high marks to some computer science programs but felt others need improvement in quality. Many were sympathetic to the difficulties university administrators face in reallocating scarce resources and were aware that the public colleges and universities were underfunded. While they expressed disappointment at MIT's refusal thus far to develop a large-scale part-time graduate engineering degree, at the same time they had grudging respect for the Institute's policy on this question.

But company officials had criticisms as well. Most believed that the state's four year colleges and universities had an insufficient number of technology course offerings. However, after stressing they wanted to see more of a high technology thrust in the curriculum, they often then added comments favorable to the liberal arts. "I don't want a society dominated by scientists and engineers," said one. Many brought up the traditional business complaint that schools, with perhaps the exception of Northeastern, are inadequately attuned to labor market trends and care little about student career placements. Some admitted that companies did a poor job of communicating their changing needs for personnel. "Academic institutions have no sense of urgency" about responding to changes in workforce demands, argued one human resources administrator. He claimed, and others agreed, that while "industry moves at 60 miles per hour, the educational sector moves at only 15 miles per hour." Another manager, who had formerly been an administrator in the state public higher education system, spoke disparagingly of the bureaucratic maze which slowed down the adoption of new programs: "By the time a program is approved in public higher education, the need has gone or Northeastern has done it."

Others saw institutions of higher learning as bumbling in their efforts at approaching industry for help. One executive, for example, cited the failure of schools to write high quality, focused requests for company support. Others cited what they felt was the narrow arrogance of some schools who wanted corporate money but no advice on the development of computer science and other curricula. They argued that many schools have failed to form viable employer advisory boards for

fledgling programs. The training director of one large firm commented that those schools which were not arrogant often veered to the other extreme of "pandering" to companies' short-term needs. Others pointed out that no university has developed a systematic sequence of retraining programs that would prevent experienced engineers from becoming obsolete.

College and university officials generally have ambivalent feelings about their relations with the high technology sector. One university president observed that executives from electronics and computer companies were easier to work with than other businessmen because they are focused in what they want from the university, and are idea oriented and creative. They are "not very different from university faculty types," he said. He added that while they often have a narrow perspective on what they want ("more engineers, period"), they have also become broader in their understanding of the mission of a comprehensive university. Many administrators observed that several years ago high technology executives approached university relations primarily from the standpoint of pressuring the schools to produce more engineers. But university officials pointed out that business attitudes have changed so that they now ask how they can help engineering education. Many were moderately hopeful that some money would be raised through the "two percent solution" campaign of the Massachusetts High Technology Council, and they were pleased that several executives were taking the lead in trying to convince the high technology business community to make contributions. Public college and university administrators, like their community college counterparts, were also approving of the presence of high technology representatives on the Board of Regents. The industry advisory board of one public engineering school has been instrumental in successfully lobbying the state legislature for more money for laboratory facilities at that school.

With the exception of MIT, however, college and university officials are generally critical of the level of high technology corporate giving to their institutions. "Companies here are young and are not yet socialized to the tradition of charitable giving," observed one university president. Many believed that the $14 million contribution goal of the

Massachusetts High Technology Council fund drive (two per cent of R and D budgets) was set too low, significantly below federal goals of 5 per cent of pre-tax earnings. (U.S. corporations give, on the average, less than 1 per cent of pretax earnings to educational and charitable institutions.)[24] Most felt that, with the exception of a small number of firms, companies give far too little. Some of the schools acknowledged they had only begun approaching companies recently for donations while others, especially state colleges, asserted they lacked the personnel to initiate contacts with the firms. The ties that did exist came largely through their adjunct faculty who held industry positions. Several college presidents who are experienced fundraisers were generally despairing of the low level of financial support from all business sectors.

One university official who has worked closely with high technology industry characterized university-business ties as "a struggling relationship." He and others cited several difficulties in developing collaborative efforts: the diverse nature of the companies and their frequent inability to agree on common policies; the fact that firms' educational efforts are usually fragmented and not fully institutionalized; the relative slowness of most companies to establish systematic and enduring recruiting efforts with the schools' new graduates (instead of always "pirating" personnel from other firms); and the paucity of companies interested in a sustained work-study/cooperative placement program for students. Others claimed that the rapid growth rates of the companies made it hard to nurture long-lasting ties. Several stressed that such ties, in order to be effective, had to be with high level executives who had more influence and longer tenure in companies than middle managers.

Educators also pointed out that the failure of industry associations to lobby for federal funds for engineering and science education contradicted their own best interests. "Industry is sticking its head in the sand by not going to Washington and talking about the national crisis in engineering education," argued one college president. "It is a national problem and we have no national policies . . . The companies

believe in 'small government' and are thus caught on the horns of a dilemma." Several claimed that it would take a crisis of some sort (e.g., losing a significant share of the minicomputer market to Japan) before business acted at the federal level on educational issues. "Companies really need to be scared before they will get their act together and lobby for federal support" commented the coordinator of a large university-industry program.

Just as corporate officials sometimes criticized the schools for the long lag in their response to labor market changes, university officials faulted industry for having such a short-term perspective. For example, they felt that most companies had not developed "mature" human resource policies that encouraged the systematic retraining and development of their experienced engineers throughout their careers. They argued that "high tech hires in fits and starts" with little planning beyond the next economic quarter. Some administrators felt they should speed up their institution's response times, but others defended the long-range planning cycles of colleges and universities. Faculty critics, citing the fact that a small proportion (less than three per cent) of Massachusetts workers are employed as technical professionals in high technology firms, questioned whether dramatic curricular changes should be implemented to accommodate the needs of that modest share of the employment market. Economist Peter Doeringer has summarized the colleges' viewpoint well:

> For a variety of reasons, existing institutions in the higher education sector cannot and should not respond fully to the shifting needs of the economy . . . Substantial programs of basic research cannot be undertaken as short-term commitments, teaching is built around long-duration degree-granting programs; laboratory facilities cannot be built overnight; and state legislatures are not likely to provide the budgetary flexibility needed to underwrite such responsiveness.[25]

Despite these varying perspectives, however, industry and educational officials have reached a rough consensus that curricula of institutions of higher learning need to be weighted more toward scientific and technical subjects than they have been previously. Student demand, if nothing else, provides the impetus for program shifts.

The Question of the Engineering Shortage

The majority of the college and university administrators interviewed voiced moderate skepticism of industry projections for engineers and computer scientists. Still haunted by the widespread layoffs of engineers in the early 1970s, they are reluctant to institute enormous expansion programs in engineering.[26] A lively debate among labor economists, engineering society spokespersons, and industry officials is taking place over this issue. Some academic observers and representatives of engineering groups argue that if the supply of engineers is as constricted as industry people claim, engineering salaries would be rising faster than they are currently, and older engineers would be utilized more efficiently. (The argument on salary levels is especially applied to Massachusetts where engineers and other high technology workers are paid less than the average compensation of comparable workers in other states.)[27] They claim that industry simply wants to expand the engineering labor supply in order to depress salaries and to have a better selection of personnel. But high technology companies dispute these claims and argue intensely that the lack of trained technical workers is already having a direct impact on their ability to get new products on the market.

Amidst the controversy, a middle ground view among the educators emerged from the interviews. While they are wary about expansion of engineering programs, they generally believe industry claims about the strength of the long-range job outlook for engineers and computer scientists. Paul Gray, President of MIT, cites three factors which will continue to generate demand for technical professionals: the need for energy alternatives in our society; the mushrooming of applications of microprocessors; and future opportunities for applications of genetic engineering.[28] The administrators agree that even if engineering jobs become scarcer in the future, technically trained people can find other positions (e.g., in marketing) where their backgrounds are useful. A common theme expressed was that "if anyone survives in the future, it will be the individual with technical training."

Academic analysts of this issue point out that engineering shortages will probably exist only in some regions and in some subfields. Company officials interviewed stressed their need for electrical and computer engineers, fields where they felt the demand would hold up for some time. They acknowledged that firms are all competing for a small pool of top flight talent, "the kind who will really make a difference to the company."

Thus, while there is some questioning of future projections of technical professionals, educators are cautiously proceeding with expansion of programs in the belief that new technologies and their applications are the wave of the future. Clearly, tensions exist between industry and academe, but the relations between companies and colleges and universities are closer than those between firms and other sectors of the educational system.

IV. CONCLUSION

As American industry creates the "new information society," the schools which train their future workers face serious problems at all levels. Enrollments in technology-oriented programs are soaring at the two and four year college levels but budgetary constraints are choking the flow of newly-trained personnel. High school mathematics and science enrollments in Boston's 128 suburbs, already high by national standards, are growing modestly and interest in computers abounds. But achievement levels among the state's teenagers have declined and teachers complain of less motivated students. Moreover, the dual effects of declining enrollment and budget reductions have caused cutbacks in academic programs and the layoffs of a generation of younger teachers. The atmosphere of demoralization which currently enshrouds public education contrasts with the upbeat ambience of high technology firms.

The response of Massachusetts' high technology companies to the deterioration of the educational environment around them has varied depending on the level of education involved. Corporate concern has focused most intensely on the needs of engineering schools. Ties between the companies and MIT have historically been very close and continue to be strong. Collaborative relations between the firms and less elite colleges and universities are less frequent but occur more often than they do between industry and the two year colleges. The commitment of industry resources, however, appears to be insufficient to meet the financial needs of engineering and other kinds of technical education. Yet industry associations shy away from calling for federal support.

At the secondary school level, the Massachusetts High Technology Council supported a tax reduction measure, Proposition 2½, which has had the unintended effect of cutting resources for school programs, including mathematics, science and vocational education. The Council, however, and several non-Council high technology companies have made some efforts to provide aid of various kinds to selected high schools. But these efforts are usually isolated, small scale affairs that make no visible change in

school programs. The obstacles to industry-education cooperation at this level are formidable. The national Administration's proposals for a "new partnership" between business and public education are unlikely to lead to solid programs of measurable impact.

The response of American education to the economic transformations wrought by modern electronics is uneven and constrained by forces largely beyond its immediate control. Without national direction and support, it is unlikely that a satisfactory response will be forthcoming in the 1980s.

REFERENCES

Introduction and Part I

1. Elizabeth Useem, "Education and High Technology Industry: The Case of Silicon Valley," Economics of Education Review, Vol. 3, No. 2, Spring, 1983. A lengthier unpublished paper of the same title is available from the author.

2. According to the Massachusetts Division of Employment Security (1981) and Department of Manpower Development (1979), high technology industries have the following characteristics: a highly skilled employee base, including a high concentration of scientists and engineers; rapid growth rates; high ratios of research and development expenditures to sales; high value-added products; and world-wide markets for products. These labor-intensive industries include the manufacture of drugs; ordnance and accessories; office computing and accounting machines; electrical and electronic machinery, equipment and supplies; guided missile and space vehicles and parts; miscellaneous transportation equipment; and measuring, analyzing and controlling instruments, including photographic, medical and optical goods. Certain service industries are also considered to fall into the high technology category--computer programming services, commercial research and development laboratories, some business management and consulting services, engineering and architecture services and some non-profit educational, scientific and research organizations.

3. Gene Bylinsky, The Innovation Millionaires, New York: Charles Scribner's Sons, 1976. See also "Center of a New World, Parts I, II, and III," Christopher Rand, The New Yorker, April 11, 1964 (pp. 43-90); April 18, 1964 (pp. 57-107); and April 25, 1964 (pp. 55-129).

4. Commonwealth of Massachusetts, Division of Employment Security, High Technology Employment in Massachusetts and Selected States, Eugene Doody and Helen Munzer, Boston, Massachusetts, March, 1981.

5. Bennett Harrison, Rationalization, Restructuring and Industrial Reorganization in Older Regions: The Economic Transformation of New England Since World War II, Working Paper No. 72, Joint Center for Urban Studies of MIT and Harvard University, 1982; see also U.S. Department of Labor, A Generation of Change in the New England Employment Structure, 1947-1979, Bureau of Labor Statistics, New England Regional Office, Boston, Massachusetts, 1981.

6. Julie K. Nickerson, The 1982 Outlook for Capital Spending Among New England Manufacturing Firms, The First National Bank of Boston, March, 1982.

7. Lynn E. Browne and John S. Hekman, "New England's Economy in the 1980s," New England Economic Review, Federal Reserve Bank of Boston, January/February, 1981, pp. 5-16.

8. Ibid.

9. Coopers and Lybrand, Results of Survey on Human Resource Needs, Massachusetts High Technology Council, Boston, January, 1981.

10. A total of 130 unstructured interviews averaging one hour in length were conducted. Most respondents (109) were seen in their offices and the rest were interviewed on the telephone. I spoke with 42 educators working with public schools: 16 chairs of secondary mathematics and science departments; 7 high level administrators; 12 vocational and industrial arts educators; and 7 other school personnel such as guidance counsellors. I interviewed 14 officials at six two year colleges, including 5 presidents of those schools. Three administrators of proprietary schools were included in the study. Also interviewed were 22 officials at colleges and universities: 4 university presidents; 7 deans of engineering and computer science chairs; 5 other high level university administrators; and 6 other university faculty members who are involved in industrial relations. Seven government officials were contacted as well as 6 individuals who have been leaders of organizations which coordinate industry-education activities. Thirty-six industry managers, executives or representatives of trade associations were interviewed, at least one official from the 9 high technology companies which currently employ more than 5000 people and at least one from 8 companies employing between 1000 and 5000 workers.

11. Samuel S. Peng, William B. Fetters, and Andrew J. Kolstad, High School and Beyond: A National Longitudinal Study for the 1980s, National Center for Education Statistics, U.S. Department of Education, Washington, D.C., April, 1981. The High School and Beyond Survey was administered in the spring of 1980 by the National Opinion Research Center (NORC), sponsored by the National Center for Education Statistics of the U.S. Department of Education. The national study, the first wave of a longitudinal survey of 28,000 senior and 30,000 sophomores, utilized a stratified probability sample of students from 1015 public and private schools. The national sample was drawn to include representative sub-samples of regions of the country, including New England, and of a handful of states, including California. The sample of Massachusetts students in the survey did not form a representative sub-sample of the state's students and thus could not be analyzed separately. A summary of the California data was made available to this researcher by officials of the California Assessment Program of the California Department of Education.

12. U.S. Department of Education, "Statistics of Public School Systems, Fall, 1980," Press Release, Washington, D.C., June 25, 1981. The national average per pupil expenditure was $2406 in 1980 compared to $3174 in Massachusetts.

13. W. Vance Grant and Leo J. Eiden, Digest of Education Statistics, National Center for Education Statistics, Washington, D.C.: U. S. Government Printing Office, 1980, p. 77.

14. San Jose Mercury, May 3, 1982, p. 6B.

15. U.S. Department of Education, "Statistics of Public School Systems, Fall, 1980," Press Release, Washington, D. C., June 25, 1981.

16. W. Vance Grant and Leo J. Eiden, Digest of Education Statistics, National Center for Education Statistics, Washington, D.C.: U.S. Government Printing Office, 1980, p. 50.

17. Nancy B. Dearman and Valena Plisko, The Condition of Education, 1981 Edition, National Center for Education Statistics, U.S. Department of Education, Washington, D.C., 1981, p. 80.

18. The Boston Globe, April 21, 1982, p. 21; The New York Times, April 20, 1982, p. 1.

19. Lynn E. Browne, "A Quality Labor Supply," in John C. Hoy and Melvin H. Bernstein (eds.), New England's Vital Resource: The Labor Force, New England Board of Higher Education, Washington, D.C.: American Council on Education, 1982. This chapter is an excellent review of the condition of public education in New England.

20. Admissions Testing Program of the College Board, "National Report on College-Bound Seniors, 1981," and "Massachusetts College Bound Seniors, 1981," Waltham, Massachusetts, 1981. Data on the percentage of Massachusetts seniors taking the SATs were obtained from the College Board office and the Massachusetts State Department of Education.

21. Lynn E. Browne, "A Quality Labor Supply," in Hoy and Bernstein (eds.), New England's Vital Resource: The Labor Force, New England Board of Higher Education, Washington, D. C.: American Council on Education, 1982, pp. 82, 84.

22. James W. Loewen, "'Truth in Testing' and Racial and Rural Discrimination,'" Testimony before the Constitutional and Administrative Law Committee, Maryland House of Delegates, March 8, 1980.

23. National Assessment of Educational Progress, Three National Assessments of Science: Changes in Achievement, 1969-77, 1978; Changes in Mathematical Achievement, 1973-78," 1979; Three National Assessments of Reading: Changes in Performance, 1970-80, 1981; Education Commission of the States, Denver, Colorado.

24. Massachusetts State Department of Education, Massachusetts Educational Assessment Program: Mathematics 1974-1975; Massachusetts Educational Assessment Program: Science and Ecology 1976-1977; Massachusetts Statewide Educational Assessment, 1977-78, Summary and Interpretations: Reading, 1978, Boston, Massachusetts.

25. The Boston Globe, October 28, 1981.

26. George Masnick, "Demographic Influences on the Labor Force," in Hoy and Bernstein (eds.), New England's Vital Resource: The Labor Force, New England Board of Higher Education, Washington, D.C.: American Council on Education, 1982.

27. The Boston Globe, citing 1980 Census data, April 21, 1982, p. 21.

28. George Masnick, "Demographic Influences on the Labor Force," cited above, p. 54.

29. Proposition 2½ limits property taxes to 2½ percent of a municipality's full and fair cash value of property. It requires a municipality above this limit

(some small towns were below already) to reduce its current levy by 15 percent each fiscal year until the levy is at the 2½ limit. The Massachusetts Department of Revenue claims that 40 of the state's 351 cities and towns are bearing the brunt of the revenue losses, including Boston, Brookline, Cambridge, New Bedford, Brockton, Lynn, Quincy, Revere, Somerville, Springfield, Worcester and Watertown. (The Boston Globe, March 5, 1982, p. 13) During the first year of the cuts (1981-82), many municipal officials avoided dramatic cuts in services by revaluating property and receiving increased state aid. (The Boston Globe, March 14, 1982, p. 31).

30. Massachusetts Association of School Committees, "The Impact of Proposition 2½ on the Public Schools," Boston, Massachusetts, April, 1982.

31. The Boston Globe, April 5, 1982, p. 13.

32. A.T. Dunathan, "Where Have All the Teachers Gone?" School and Community, September, 1979; Clyde A. Paul, "Bald Eagles, Sperm Whales, and Mathematics Teachers," Mathematics Teacher, December, 1979, pp. 424-427; Clyde A. Paul, "The Mathematics Teacher Shortage: Some Solutions," Mathematics Teacher, March, 1981, pp. 173-178; T.G. Howe and J.A. Gerlovich, National Study of the Estimated Supply and Demand of Secondary Science and Mathematics Teachers, unpublished paper, November 6, 1981; Zalman Usiskin, "The Secondary School Mathematics Curriculum as a Cause of the Shortage of Mathematics Teachers," paper delivered at the meetings of the American Association for the Advancement of Science, January, 1982; Sarah E. Klein, President of the National Science Teachers Association, "Testimony to Committee on Labor and Human Resources of the United States Senate," April 15, 1982.

33. National Science Foundation, What Are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field, Washington, D.C.: National Science Foundation, 1979, pp. 47, 127.

34. Christine LeCam, The Public Vocational Education System as a Potential Source of Labor Supply to Selected High Technology Occupations, Massachusetts Department of Manpower Development, Boston, Massachusetts, June, 1980.

35. Michael Hilliard and James Parrot, The Massachussachusetts High Technology Council: An Assessment of its Public Policy Agenda, unpublished paper, Department of Economics, University of Massachusetts, Amherst, Massachusetts, 1982. Contribution figures are provided by the Office of Campaign and Political Finance, Boston, Massachusetts.

36. Eric Lundquist, "High Tech on the Hot Seat," Boston Magazine, February, 1981, pp. 78-118.

Part II

1. John C. Hoy, "An Economic Context for Higher Education," in John C. Hoy and Melvin H. Bernstein (eds.), Business and Academia: Partners in New England's Economic Renewal, New England Board of Higher Education, Hanover: University Press of New England, 1981, pp. 12, 24.

2. All of the comparative figures on higher education are from D. Kent Halstead, How States Compare in Financial Support of Higher Education, 1981-82. National Institute of Education, Washington, D.C., February, 1982, pp. 24, 25, 30.

3. Halstead, ibid., p. 8.

4. Ray Stata, "Appendix II. Perspectives of Two Business Leaders," in Hoy and Bernstein (eds.), Business and Academia: Partners in New England's Economic Renewal, New England Board of Higher Education, Hanover: University Press of New England, 1981.

5. Christine LeCam, The Public Vocational Education System as a Potential Source of Labor Supply to Selected High Technology Occupations, Massachusetts Department of Manpower Development, Boston, Massachusetts, June, 1980.

6. Karen Fulbright, "Impact of Decreased Defense Spending on High Technology Industries in New England," The First National Bank of Boston, September, 1981.

7. Colorado's State Board of Community Colleges and Occupational Education currently projects 1405 job openings in electronics technology between 1983 and 1987 and the training of 3105 new electronics technicians in the state during that same period.

Part III

1. American Electronics Association, Technical Employment Projections 1981-1983-1985, Palo Alto, 1981; Coopers and Lybrand, Results of Survey on Human Resource Needs, Massachusetts High Technology Council, Boston, January, 1981.

2. New England Board of Higher Education, A Threat to Excellence: A Preliminary Report of the Commission on Higher Education and the Economy of New England, Wenham, Massachusetts, March, 1982, pp. 9, 17.

3. John C. Hoy and Melvin Bernstein, (eds.), Business and Academia: Partners in New England's Economic Renewal, New England Board of Higher Education, Hanover: University Press of New England, 1981; New England's Vital Resource: The Labor Force, New England Board of Higher Education, Washington, D.C.: American Council on Education, 1982; see also A Threat to Excellence, cited above.

4. Joan H. Grebe, "Appendix: Engineering and Technological Education in New England," in Hoy and Bernstein (eds.), New England's Vital Resource: The Labor Force, cited above, pp. 131-149.

5. Admissions Testing Program of the College Board, "National Report on College Bound Seniors, 1981," Waltham, Massachusetts, 1981.

6. Patrick J. Sheridan, "Engineering and Engineering Technology Enrollments, Fall, 1980," Engineering Manpower Commission, Engineering Education, October, 1981, pp. 45-52.

7. Joan H. Grebe, "Appendix: Engineering and Technological Education in New England," in Hoy and Bernstein (eds.), New England's Vital Resource: The Labor Force, New England Board of Higher Education, Washington, D.C.: American Council on Education, 1982, p. 144.

8. Peter Doeringer, Patricia F. Pannell, and Pankaj Tandon, "Market Influences on Higher Education: A Perspective for the 1980s," in Hoy and Bernstein (eds.), Business and Academia: Partners in New England's Economic Renewal, New England Board of Higher Education, Hanover: University Press of New England, 1981, p. 52.

9. Chronicle of Higher Education, November 25, 1981, p. 10. (Citation of a study conducted for the National Science Foundation by the American Council on Education.)

10. National Science Foundation, Science and Engineering Education for the 1980s and Beyond, Washington, D.C., October, 1980.

11. Chronicle of Higher Education, November 25, 1981, p. 10.

12. Chronicle of Higher Education, December 2, 1981, p. 3.

13. Chronicle of Higher Education, December 16, 1981, p. 7.

14. American Electronics Association, Pat Hill Hubbard, Planting the Engineering Seed Corn, Palo Alto, California, October, 1981.

15. John B. Duff, Speech delivered at Conference on Engineering Education, Massachusetts High Technology Council, Natick, Massachusetts, February 10, 1982.

16. American Electronics Association, Pat Hill Hubbard, Planting the Engineering Seed Corn, Palo Alto, California, October, 1981; Massachusetts High Technology Council, "Position on University/Industrial Relations," statement of MHTC distributed at February 10, 1982 Conference on Engineering Education, Natick, Massachusetts; The Boston Globe, February 9, 1982, p. 45.

17. Peter B. Doeringer and Patricia Pannell, "Manpower Strategies for New England's High Technology Sector," in Hoy and Bernstein (eds.), New England's Vital Resource: The Labor Force, New England Board of Higher Education, Washington, D.C.: American Council on Education, 1982, p. 27.

18. Chronicle of Higher Education, April 14, 1982, p. 9; American Electronics Association, Pat Hill Hubbard, Planting the Engineering Seed Corn, Palo Alto, California, October, 1981.

19. Quotes of George A. Keyworth, head of the White House Office of Science and Technology Policy, Electronic News, May 17, 1982, p. H.

20. Task Committee on Engineering Education, "Report to the Board of Direction," Proceedings of the American Society of Civil Engineers, Vol. 108, January, 1982.

21. The Boston Globe, September 1, 1981, p. 31.

22. The Centennial Study Committee at MIT has produced several working papers, authored by Myron Tribus, L.D. Smullin and R. M. Fano, dealing with the issue of life-long education for engineers. MIT's Centennial Conference in the winter of 1982 centered on this theme.

23. The Boston Globe, April 29, 1982, p. 38.

24. The Conference Board, Annual Survey of Corporate Contributions, 1981 Edition, New York, New York, 1981.

25. Peter B. Doeringer, Patricia Pannell and Pankaj Tandon, "Market Influences on Higher Education: A Perspective for the 1980s," Business and Academia: Partners in New England's Economic Renewal, New England Board of Higher Education, Hanover: The University Press of New England, 1981, p. 73.

26. For an excellent account of the impact of engineering layoffs on Route 128 in the early 1970s see Paula Leventman, Professionals Out of Work, New York: The Free Press. 1981.

27. Joan H. Grebe, "Appendix: Engineering and Technological Education in New England," in Hoy and Bernstein (eds.), New England's Vital Resource: The Labor Force, New England Board of Higher Education, Washington, D.C.: American Council on Education, 1982, p. 148; see also Commonwealth of Massachusetts, Division of Employment Security, High Technology Employment in Massachusetts and Selected States, Eugene Doody and Helen Munzer, Boston, Massachusetts, 1981.

28. Paul Gray, "The Crisis in Engineering Education," Electronic Engineering Times, October 12, 1981, p. 96.